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Bacteriosis (Blight) of the English Walnut in California and Its Control

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CONTENTS

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INTRODUCTION

The present paper is concerned primarily with results obtained in spraying experiments for the control of bacteriosis (blight)[3] of the English walnut that have been conducted on a large scale at widely separated points in California since 1927.

Walnut bacteriosis is not a new disease. In relation to the history of walnut culture in California it may be considered rather an old one. Between the time when bacteriosis was first observed over forty years ago and the present, much important information about it has been obtained and published. For the sake of clarity, however, as well as to make the control data presented herein easier reading for the grower for whom this paper was written or for the plant pathologist who may never have made a study of the disease, a digest of the known basic facts concerning it has been prepared.

It is not in the matter of laboratory studies of the organism that research has lagged but rather in the matter of control. The control of parasitic disease in plants lies chiefly along two lines: the development of immune or highly resistant varieties, and the use of preventive sprays or treatments. Although considerable effort has been expended, no immune or even highly resistant variety of English walnut has been found to date. Some so-called "blight-resistant" varieties have been announced from time to time in the past, but none has measured up to the expectations. Their apparent resistance seemingly depends not upon any inherent physiological properties of the trees but, rather, merely upon the extent to which their new growth escapes rain in the spring as the result of late foliation. The Eureka variety, once acclaimed as highly resistant and even immune to bacteriosis in southern California, is now known to be very susceptible there in occasional years when late spring rains pre-

[1] Received for publication November 23, 1932.

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[3] While the term "bacteriosis" is far more descriptive and definitive than "blight," it is not wholly satisfactory. Crown gall, a bacterial disease of walnuts, is technically a case of true bacteriosis also. As used throughout this paper the term "bacteriosis" refers exclusively to the disease commonly called "walnut blight," "black spot," "black plague" (peste negra), etc., and caused by the attack of the bacterial organism originally named *Pseudomonas juglandis* by Pierce.

vail. In the damper San Francisco Bay region this variety may be attacked severely, and in Oregon it is so very susceptible that it is regarded commercially as a failure and seldom planted. The same is true of many other varieties.

Spraying to control bacteriosis has met with little success in the past. This may be due in part to the fact that practically all efforts along this line were made during the winter rather than during the growing season when the disease is active. Until comparatively recent years sprays applied at any time of the year might easily have been unsuccessful, especially upon mature trees, which usually attain huge size, because with older types of spray equipment it was virtually impossible to reach all parts of the trees and spray them properly. Within the past decade power-spraying has undergone great changes for the better, but even today to insure thorough coverage it is still necessary to spray very large trees with specially devised long-range guns from a tower erected on top of the spray rig.

In spite of the limitations of the spray machinery of his day, the late Newton B. Pierce, who discovered the cause of the disease and named the organism responsible for it, claimed that applications of bordeaux would reduce infection appreciably. Pierce's reports, written in popular vein and practically devoid of experimental data, were published almost exclusively in several popular magazines which were obtainable only by subscription or purchase. It is not likely that a very large number of walnut growers in California at the time ever saw his articles. In none of his papers does Pierce mention how strong a spray he used, and discrepancies exist in his statements as to just when he applied it. In reading his reports one cannot help feeling that they are fragmentary and merely forerunners of a complete paper or bulletin in which his experimental data would be set down in detail or at least in a more tangible form. Such a bulletin never appeared. Eventually he did publish a technical description of the disease and of the causal organism (42),[4] but in this final report he did not mention spraying at all.

The above criticisms of Pierce's work are not offered with any intention of disparagement whatever. His laboratory studies still remain the basis of all subsequent work by later workers. They are offered merely as a possible explanation of why this phase of his work, which has been verified by the experiments reported in this paper, failed to make a permanent impression on the growers of his day.

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[4] Reference is made in parenthesis to "Bibliography," page 83. Numbers in boldface or heavy type refer to publications particularly pertinent to the subject under discussion. The publications in the bibliography deal primarily with walnut bacteriosis, whereas those cited in footnotes ordinarily do not.

With the walnut industry firmly established in California and grown to its present considerable proportions it seemed logical to attack the problem of control from the standpoint of sprays rather than from that of resistant varieties, to afford, if possible, some relief to the great number of growers whose orchards are severely affected by bacteriosis.

An attempt has been made to have the bibliography given on page 83 as complete as possible up to 1932, when this paper was written. In general unsigned popular articles in magazines or newspapers which have contributed no original research data or observations have been omitted.

HISTORY AND GEOGRAPHIC DISTRIBUTION OF WALNUT BACTERIOSIS

THE POSSIBILITY OF ITS BEING OF FRENCH ORIGIN

The organism which causes walnut bacteriosis is unable to reproduce or even to live for more than a relatively short period in the soil. Similarly it is known to attack only the English walnut and rarely its hybrids. Therefore it seems reasonable to assume that it could not have existed in the absence of walnuts in those localities where it is recognized now, and presumably it was disseminated about the globe on infected stock.

Suspicion often has been pointed at France as the source of the disease, and not without reason, since the walnut industry there is an old one, and many of the plantings made throughout the world during the past fifty or sixty years are easily traceable to nuts and scions imported directly from that country.

In 1907 C. O. Smith (62)[5] observed characteristic lesions on scions imported into California from France. When the scions were grafted on black walnut, typical bacteriosis developed on the new growth close to the old wood. No other trees in the vicinity were diseased at the time, and no new shoots other than those from the French scions ever developed bacteriosis. Also, according to C. O. Smith (51, 53) R. E. Smith saw bacteriosis in walnut orchards in France in 1913.[6]

No French writers have reported walnut bacteriosis in their country, but very recently Wormald and Hamond (107) in England proved con-

[5] Although the bulletin given as citation 62 was written jointly by several authors, credit for the special section on walnut bacteriosis is given to C. O. Smith.

[6] R. E. Smith was thoroughly familiar with walnut bacteriosis at the time he went abroad and is not likely to have been mistaken in its identity. In personal conversation with me he has described the disease which he saw in France and which beyond all reasonable doubt must have been bacteriosis. However, since no cultures were made, the proof of its identity might be challenged on technical grounds. He saw bacteriosis in the vicinity of Grenoble, France, and also near Sorrento, Italy.

clusively that it occurs in France. They conducted successful inoculation experiments with pure cultures of the organism isolated from diseased walnuts growing in the Isère Department, France, and from stem lesions in the same vicinity. Cultural studies showed the organism to be identical with the walnut-blight organism in England and in California.

HISTORY OF THE DISEASE IN CALIFORNIA

About 1890 the disease was first observed in Los Angeles County on trees which had been obtained from a nursery in Orange County. This nursery is known to have imported walnut trees from France a few years earlier. At practically the same time, or very soon thereafter, the disease appeared in Orange County itself (51, 52, 53, 56, **62**). Apparently regarded as a curiosity at first, bacteriosis became so increasingly destructive in southern California and spread so rapidly to other portions of the state that the United States Department of Agriculture detailed Newton B. Pierce[7] to make a study of it. The progress that Pierce made in his work is suggested in the annual report of the Secretary of the United States Department of Agriculture (25) for 1893. By that time the disease was suspected of being of bacterial origin, but inoculation studies to prove the point had not yet been made. In 1896 Pierce wrote a letter describing bacteriosis to the editor of the California Fruit Grower who published it (37). One may gather from the letter that he had isolated the causal organism and with pure cultures had successfully produced hundreds of artificial infections. He also gave the first really accurate description of the disease that had appeared. In subsequent popular magazine articles Pierce reported its latest geographic distribution and very briefly referred to his control experiments (38, 39, 40, 41).

In 1901 he published a technical description of both the causal organism and the disease, referring to the latter as "bacteriosis," as he had done in earlier papers (42).

Around 1900, bacteriosis had become so destructive that the California Walnut Growers Association offered rewards as great as $20,000 for a suitable means of combating it.

In 1905 the California State Legislature appropriated $4,000 to the University of California for the study of walnut bacteriosis, and a laboratory was opened at Whittier, in Los Angeles County,[8] with A. M.

[7] Mr. Pierce's title was Assistant Plant Pathologist, in charge of the Pacific Coast Laboratory of the Division of Vegetable Physiology and Pathology of the United States Department of Agriculture at Santa Ana, California. This laboratory is no longer in existence.

[8] This laboratory is no longer in existence.

West in charge, working under the direction of R. E. Smith. Mr. West confirmed Pierce's identification of the cause of the disease but never published his results. The work was then taken over by R. E. Smith, C. O. Smith, and H. J. Ramsey (44, 51, 52, 53, 54, 55, 56, 59, 60, 61, 62, 63, 64, 65), who secured and published much data on walnut blight, as well as walnut culture in general. In this work no specific method of control for bacteriosis was developed.

From 1913 to 1915, W. S. Ballard of the United States Department of Agriculture conducted spraying experiments in the Vrooman orchard at Santa Rosa. The results were never published.

In 1920 Fawcett and Batchelor (23) published results of experiments to control the disease. They found neither a single application of spray very early in the season nor the careful removal of dead wood or infectious material from the trees to be effective.

In 1926 the California Walnut Growers Association, chiefly at the behest of members living in central California, appropriated $2,000 for the further study of the control of bacteriosis, and the writer was placed in charge of the project. The results obtained in the experiments, which were started in the spring of 1927, are given in the present paper.

HISTORY AND GEOGRAPHIC DISTRIBUTION OF THE DISEASE IN OTHER PARTS OF THE UNITED STATES

Oregon was the second state in the Union to report bacteriosis of walnuts when Lewis (31) first described it in 1906. The disease is now recognized in all the walnut-growing districts of that state, and reports of its occurrence and losses occasioned by it have appeared with unusual frequency (1, 2, 7, 8, 9, 21, 27, 31, 33, 50, 75, 76, 77, 78, 80, 81, 82, 84, 85, 86, 88, 89, 90, 91, 92, 96, 97, 98).

Bacteriosis was next reported from Texas by Schattenberg (49) in 1908. Later Waite (68), with Schattenberg's paper in mind,[9] referred very briefly to its occurrence there. The descriptions of the disease given by Schattenberg leave doubt as to its identity.

Bacteriosis was next reported in Louisiana very briefly by Waite (68) in 1914. McMurran (32) also includes Louisiana in his list of states in which the disease occurs.

In 1917, McMurran (32) reported bacteriosis for the first time in Maryland, Pennsylvania, New York, Delaware, Virginia, and the District of Columbia, giving credit for the most part to Waite for diagnos-

[9] According to a personal letter to me.

ing the disease in specimens received in the government laboratories at Washington, D. C., between the years 1910 and 1916.

In 1920, Cook (83) first reported bacteriosis in New Jersey. Two additional reports of its occurrence there have since appeared (17, 85).

Bacteriosis was reported very briefly in 1920 in Alabama (83) and in 1922 in Georgia (85) by the Plant Disease Survey. These are believed to be the only references to the disease in those states.

In 1922, Dana (85) very briefly reported bacteriosis in Washington. Since then it has been reported by the Plant Disease Survey (87, 89, 90, 91).[10]

In 1929, Rosen (78) reported a severe attack of bacteriosis on the leaves of several trees at Fayetteville, Arkansas.

In 1930, the Plant Disease Survey (91) briefly reported bacteriosis in Mississippi.

HISTORY AND GEOGRAPHIC DISTRIBUTION OF THE DISEASE IN FOREIGN COUNTRIES

Reports of bacteriosis in foreign countries are given in the chronological order of their appearance.

New Zealand.—In 1900 Boucher (12) reported and briefly described bacteriosis in New Zealand before it was recognized in any other country or any state in the United States outside of California. It occurs at Auckland (12), the Nelson and Takaka districts, at Christchurch, Banks Peninsula, Timaru, Hawke's Bay, New Plymouth, and Tauranga (28, 29), and at Akaroa (5).

Russia.—An anonymous writer (4) reported bacteriosis in Russia in 1908. The report states that Jaczewski found the disease to be responsible for heavy losses on the Government estate near Sotchi, and Silantiev is said to have reported severe losses in Sotchi itself. Sotchi is near the Black Sea in the vicinity of the Caucasus Mountains. No other report of the disease in Russia has appeared.

Canada.—In 1911, bacteriosis was reported and described in Canada by Güssow (26). It was said to have occasioned severe losses for a number of years in the experimental farms at Agassiz, B. C. The trees originally came from France. No other writer has reported the disease in Canada.

Tasmania.—In 1912, bacteriosis was reported in Tasmania by Rodway (45). Walnut trees in the vicinity of Hobart were said to be severely affected. No other report of the disease on this island has appeared.

[10] Additional reports of the occurrence of bacteriosis over a widespread area in Washington have been received from Dr. F. D. Heald, Chief of the Division of Plant Pathology, Washington Agricultural Experiment Station at Pullman.

Mexico.—In 1912, C. O. Smith (62) reported bacteriosis on walnuts growing along the Pacific Coast of central Mexico. He has made this same report elsewhere (51, 52).

Australia.—In 1914, bacteriosis was reported in Australia by Cole (15) who found it in the state of Victoria, where the trees were said to be severely affected at times. The disease is commonly referred to as "black spot" there and elsewhere on the continent. According to Cole, bacteriosis was seen in Australia as early as 1888 by Mr. Brittlebank, Pathologist of the Victoria Department of Agriculture. This is earlier than the first record of it in California by several years. Cole (16) also has reported bacteriosis in the Ardmona, Bright, and adjacent districts of Victoria.

Bacteriosis was first reported in the State of South Australia in 1922 by Osborn and Samuel (36), who observed that "during the last twenty years [it had] spread to almost all places in the State where walnuts are grown, even to trees 10 or 12 miles apart from any other." Bacteriosis has been reported as occurring specifically in the Mount Lofty Ranges and in the Auburn district by an anonymous writer (6).

Bacteriosis has been recognized in the State of New South Wales since 1903. It causes most damage in the cooler regions, particularly in the Southern Highlands, according to R. J. Noble of the Department of Agriculture of New South Wales.[11]

Chile.—Bacteriosis was reported from Chile in 1917 by Camacho (13). It is commonly known there as the "black plague" (peste negra). In 1926 Capdeville (14) further described the disease and estimated that losses reached as high as 50 per cent at Catemu, Nuñoa, and Maruecos. These are the only reports of bacteriosis from South America.

South Africa.—Doidge (18) reported bacteriosis of walnut in South Africa in 1918. It was said to occur in practically all parts of the country where walnuts are grown and was believed to have been disseminated on nursery stock originally obtained from France. Also it was believed to have been established in South Africa for some few years previous to its identification there.

The disease has been reported specifically from several localities in the Eastern Province, at Eastport, at Clocolan in the Orange Free State, at Potchefstroom in the Transvaal, at Napier in the Bredasdorp District, at Donnybrook in Natal (18, 19, 20) and in the Cango Valley of the Oudtshoorn District (19).

Evans (22) states that bacteriosis was very prevalent in South Africa in 1922.

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[11] Personal letter dated June 10, 1931.

Italy.—Bacteriosis was next reported in Italy in 1923 by Savastano (48). Ferraris (24) also has reported the disease there, giving Savastano's paper as his source of information.

The disease described by Savastano at great length and attributed by him to *Bacterium juglandis* Pierce clearly is not the disease under discussion, and accordingly, has no place in this paper.[12] It is referred to here, and Savastano's paper is included in the bibliography on page 83, because so many authors include Italy in their reports on the geographical distribution of the disease, giving Savastano as reference. Technically no absolute proof of the presence of walnut bacteriosis in Italy exists.[13]

Holland.—Bacteriosis was reported very briefly on walnuts at Zierikzee, Holland, in 1923 by van Poeteren (67). Experimental data and descriptions are lacking. No other report of the disease in Holland has appeared.

Switzerland.—Bacteriosis was reported very briefly in Switzerland in 1924 by Müller-Thurgau and Osterwalder (35). Experimental data and a suitable description are lacking.

England.—Bacteriosis was reported in England in 1927 by Wormald (69), who isolated the causal organism from leaf spots which developed on very young trees the same year that they were received from a nursery in France and planted at the East Malling Research Station. Reports by Wormald and Hamond of subsequent laboratory studies, including suitable descriptions and experimental data, have appeared (70, 71, 72, 73, 74, 94, 107).

Germany.—Whether bacteriosis actually exists in Germany is not clear from the limited information at hand, but Stapp (66) published a description of it in 1928, which was drawn from California publications, and also a technical description of the causal organism based on Pierce's studies. He refers to the disease as *Bakterienbrand der Walnüsse,* but no mention of its occurrence in Germany or elsewhere in Europe is made.

France.—The presence of walnut bacteriosis in France has been recognized definitely since 1931. See page 5.

[12] The disease described by Savastano and referred to by him as the "dry disease" is characterized by a complete desiccation of the tree, all parts being affected, including roots, trunk, branches, shoots, leaves, and fruit. Affected trees die within a few months to five years after attack. Vague physiological disturbances are noted; excessive production of fruit which fails to ripen, chlorosis, etc. Black spots appear on the leaves and nut husks, the shell and kernel may be destroyed.

Almost the entire article is devoted to a description of the disease in the roots, trunks, and branches. The black spots on the leaves and fruit, which alone seem suggestive of true bacteriosis, are scarcely more than mentioned. Savastano made no cultures, conducted no inoculation experiments.

[13] See footnote number 6, page 5.

DESCRIPTION OF BACTERIOSIS

Walnut bacteriosis is essentially a disease of the leaves, catkins, nuts, and new tender shoots of the English walnut. It never kills a tree, and, under California conditions, it rarely causes any appreciable defoliation even in years favorable to heavy infection. The developing nuts, unfortunately, are very susceptible, which fact alone makes the disease of economic importance. A fine set of nuts at the beginning of the season may be gradually decimated until not a single one remains by harvest time, and yet at close range, the tree itself ordinarily presents no unusual appearance.

In contradistinction to bacteriosis of pears and apples (pear blight, fire blight)[14] caused by *Phytomonas amylovorus* (Burrill) Bergey *et al.*, or bacteriosis of the filbert (filbert blight),[15] caused by *Phytomonas* sp., two diseases which attack all parts of their natural hosts, including fruit, leaves, branches, trunks, etc., walnut bacteriosis never attacks wood that is more than one year old. Similarly it never attacks the roots.

On the Shoots.—Bacteriosis may be expected to occur on the shoots only during that comparatively short period of a few months after their appearance while they are still green, succulent, and tender. As they toughen and become woody in structure their susceptibility diminishes. The degree to which a shoot is susceptible varies throughout its entire length. Thus the older base of a long shoot may have become fairly woody and correspondingly resistant while the growing tip is still succulent and very susceptible to attack if weather conditions are favorable. By the end of the first season, however, all parts of such shoots will have

[14] Recently C. O. Smith successfully inoculated walnut shoots and fruit with the "pear blight" organism. Lesions were produced on both which were indistinguishable from those of true "walnut blight." Natural infection of walnut by the "pear blight organism" is unknown. Smith was unable to infect pear with the "walnut blight" organism. (Smith, C. O., Pathogenicity of *Bacillus amylovorus* on species of *Juglans*. Phytopath. **21**(2):219–223. 1 fig. 1931.)

[15] Some writers consider filbert blight and walnut bacteriosis to be identical and group the literature pertaining to these two diseases together in their bibliographies. This seems inadvisable in view of the limited information on the filbert disease which has appeared.

The two diseases apparently present many characteristics in common, but they differ radically in one point; according to descriptions of it, the filbert disease may produce large cankers on the branches and trunks of the trees, whereas walnut bacteriosis cannot attack mature first-year wood, let alone the older branches or the trunk.

H. P. Barss of the Oregon Agricultural Experiment Station has probably done more work with the filbert disease than anyone else. In none of his papers does he make the positive statement that the two diseases are identical or due to the same organism. In a letter received from him while this paper was being written he definitely states that he prefers to reserve final opinion as to the relationship of the two diseases until more experimental data are available.

matured to such an extent that infection can be brought about only with the greatest difficulty, if at all.

Ordinarily infection takes place at or near the extreme tip of the shoot in the tenderest tissue. The entire tip may be killed back for a few inches and in severe cases as much as a foot or even more. But more often the infection is localized and spreads so slowly that the tip of the shoot

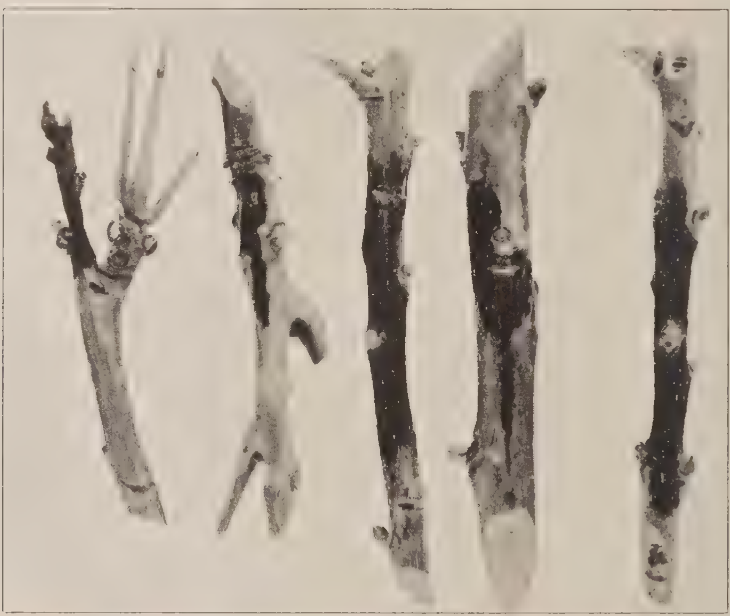

Fig. 1.—Bacteriosis of young green shoots of the English walnut. (Natural size.)

grows away from the lesion produced, leaving it farther and farther behind on the shoot. Such lesions may be very small, never attaining a diameter of more than a small fraction of an inch, or they may be several inches long and extend almost completely around the shoot. Occasionally complete girdling takes place, especially when two or more actively spreading lesions coalesce. When girdled the portion of the shoot above the lesion dies as the result of interference with the passage of sap.

The lesions may be so superficial as to involve only the bark, or so deep seated that all tissues are destroyed to the pith. It is in the diseased tissue of such lesions that the organism successfully lives over the winter (Pierce, 37, 39, 40, 41, **42**, 43; C. O. Smith, 54, **62**; and others).

The first visible appearance of the lesion on the shoot is as a minute, translucent or water-soaked dot, usually about the size of an ordinary pinhead or smaller. As the disease continues to spread the inner or older portion of the spot darkens, eventually becoming black. Surrounding

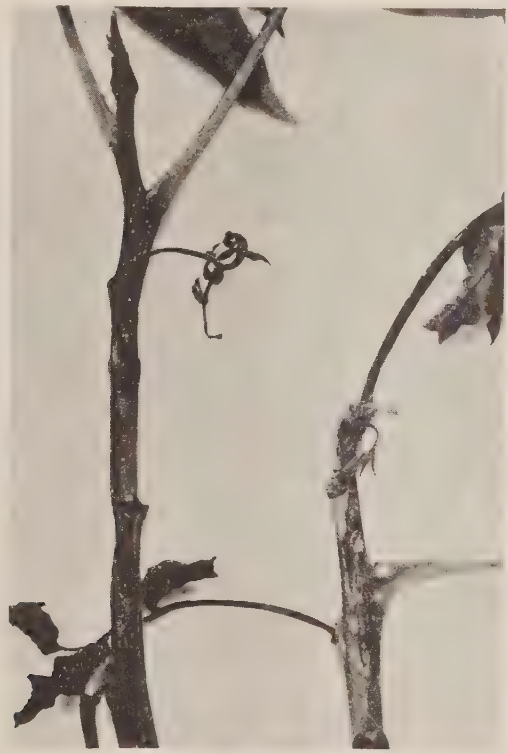

Fig. 2.—Destruction of the terminals of young green walnut shoots by bacteriosis. (Natural size. From Bul. 231.)

the black spot may be seen a narrow band of translucent, water-soaked tissue. The width of this band varies according to the toughness and resistance of the tissue itself, as well as the severity of the attack. When the disease is making little progress the band may be scarcely more than visible to the eye, but in young tender tissue with the disease in an aggressive state it may vary from one to several millimeters in width. When the disease ceases to be active altogether owing to the toughening of the tissue or to other unfavorable conditions, the band disappears entirely,

and the line between the killed, blackened area and the healthy portion is sharply defined. The margins of lesions, whether active or inactive, are generally very irregular (figs. 1 and 2).

As the disease continues to spread in a shoot, the older diseased portions dry out and become somewhat shrunken and depressed. This gives the lesion more of the characteristic appearance of a canker. Generally the epidermis in such dead areas cracks as the tissue dries out.

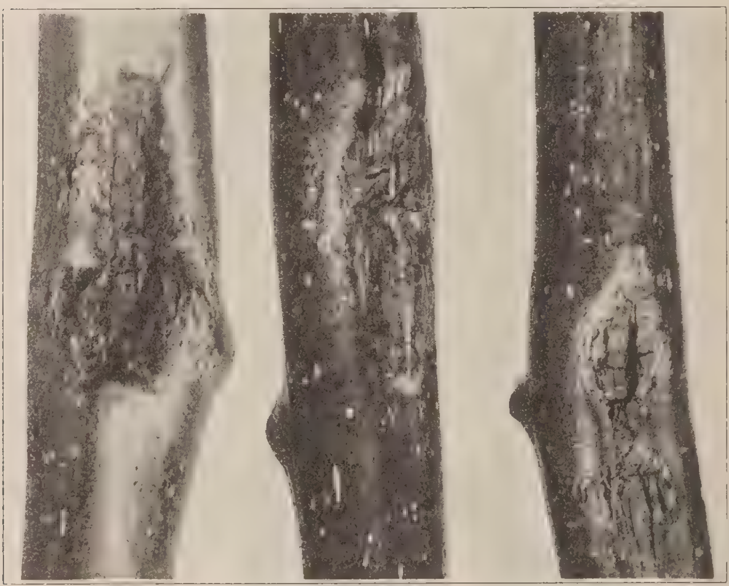

Fig. 3.—Lesions on English walnut twigs healing over the year following their production by bacteriosis. The organisms which cause the disease live over the winter in the dead and dying tissue of such cankers as these. (Natural size. Photograph by C. O. Smith.)

The dying tissue not infrequently exudes a mixture of decomposed cellular products and bacterial slime, which dries upon the surface as a frosty, whitish, flaky precipitate.

With the disease brought to a halt as a result of the toughening and lignification of the tissue, the process of healing sets in. Evidence of callus formation frequently may be seen around the edges of the cankers late the same season. Figure 3 shows cankers in the process of healing. Healing is completed in the great majority of instances during the growing season of the year following the attack, and the trees apparently are none the worse for their experience.

On the Leaves.—All parts of the leaf may be attacked, including the parenchyma tissue of the leaflets, the midribs, lateral veins, veinlets, rachis, and petiole. After infection, minute water-soaked or translucent

Fig. 4.—Leaves of English walnut affected with bacteriosis. Note that the tissue of the blade, midrib, or petiole may be affected. (Reduced.)

dots appear, which eventually enlarge and darken to a dark brown color as the tissue dies. The margins of such brown spots are a yellowish green in color, lighter than that of the normal healthy tissue adjoining. The individual spots ordinarily never attain a great size and rarely exceed

a few millimeters in diameter. Several smaller spots may coalesce, however, to form a single large one. Typical spots may be circular or irregular in shape.

At times infection may be rather severe at the tender margins of young growing leaflets. In this case a considerable killing of the tissue takes place, which results in malformations and deformities as the healthy tissue grows away from the dead areas (fig. 4).

The killing of a rachis or petiole may lead to the death of the leaflet or leaf, respectively, dependent upon it. Defoliation to any appreciable extent is rare, however.

In California, sunburn and wind damage may manifest themselves as dead irregular brown spots on the leaflets which might be mistaken for bacteriosis. Such spots, however, are confined almost exclusively to the tender, green parenchymatous tissue between the lateral veins of the leaflets, and they rarely lead to distortions or deformities. The lesions developed on leaves of trees poisoned by excessive amounts of alkali or boron in the soil have been confused by some growers with bacteriosis.

On the Nuts.—The nut may be attacked at any time after its first appearance in the spring until it is about ready to drop from the husk in the fall. The period of susceptibility, therefore, is a very long one, which fact constitutes one of the chief obstacles to an easy control of the disease.

Blossom-End Infections.—In its earliest stages of development, namely, before, during, or immediately after pollination has taken place, the nut usually is infected at the blossom-end by way of the stigma.

The blossom of the walnut is inconspicuous, consisting of two small, greenish to reddish, plume-like lobes at the tip of the tiny young nut. These lobes technically make up the stigma, which is the female reproductive process designed to receive the pollen at the time of fertilization (fig. 15, page 64). The surface of the lobes which make up the stigma is very rough and lightly coated with a sticky substance, to insure the retention of any pollen which might fall upon it. This rough, sticky surface probably holds the bacteria equally well also. The tissue of the stigma is exceedingly fragile and tender, and constitutionally adapted to easy attack by the organism. After it has become infected the stigma blackens, the first symptom of disease in it being a tiny black spot at its base or a very thin black streak on its side. From the base of the stigma, the disease penetrates the succulent young nut (fig. 5).

In California the great loss of crop unquestionably is occasioned by the blossom-end infections. The small diseased nuts, 1/8 to 1/2 inch in

diameter, are quickly abscissed or shed from the trees, and in years of severe attack the ground may be covered with them.

Although the great bulk of nuts affected at the blossom-end drop from the trees while still very small, an appreciable number do not. In those that remain the disease often seems to be temporarily arrested in its progress; the nuts continue to grow and may even reach maturity. It is not unusual, however, for bacteriosis to become active again in them at

Fig. 5.—Young English walnuts affected with the blossom-end phase of bacteriosis. (Natural size.)

a later date and destroy much husk and shell tissue. Or the disease, arrested to all outward appearances, may work inward through the shell at the blossom-end and destroy the kernel wholly or in part. Nuts containing only the blackened, shriveled remnants of kernels destroyed by bacteriosis are not uncommon at harvest and are generally referred to as "blanks." In the packing house they are referred to as "blows."

Certain strains of the Mayette, generally regarded as one of the most resistant varieties, show a peculiar susceptibility to bacteriosis at the blossom-end. In certain seasons it may be difficult to find nuts that are not affected. The disease makes little progress outside or inside, however, and is confined to a small spot at the base of the stigma. Some nuts are totally destroyed, of course, but at harvest the bulk of the crop is normal in appearance and presents little or no evidence of having been diseased so generally early in its development.

Pollination having taken place, or the period of susceptibility to pollination having passed, the stigma quickly shrivels and disappears. In-

fection at the blossom-end then ceases to take place to any great extent, and lateral or side infections become the rule.

Lateral Infections.—Lateral infections (fig. 6) may take place at any time after the nuts first appear and frequently accompany blossom-end infections, but they predominate later when the period of pollination has passed.

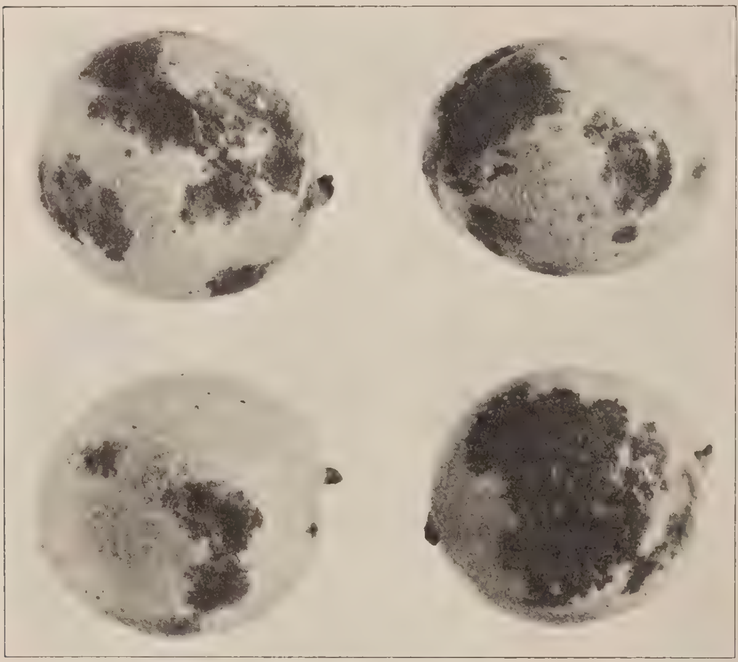

Fig. 6.—Bacteriosis of English walnuts showing lateral infections on the nuts. Note the water-soaked appearance of the tissue at the margins of some of the spots. (Natural size.)

Infections on the sides of the nuts, as on the shoots and leaves, are first visible only as minute, translucent or water-soaked dots. As the disease spreads, the older or central portions of the spots darken and finally become black. A zone or band of translucent or water-soaked tissue, already described on the shoots, and of similarly varying width, persists during the active spread of the disease and makes a border between the healthy and dying parts.

As the lesions enlarge the centers become somewhat shrunken and depressed, and not infrequently the epidermis ruptures (fig. 7).

After protracted wet weather, and particularly immediately after summer irrigation a black slimy sap (fig. 8) frequently bursts through

the epidermis of the lesions. This liquid may be so copious in amount that it collects in great drops and spatters down onto healthy leaves and nuts below. The liquid is swarming with the bacteria that cause the disease and frequently serves as a medium to introduce the organism to

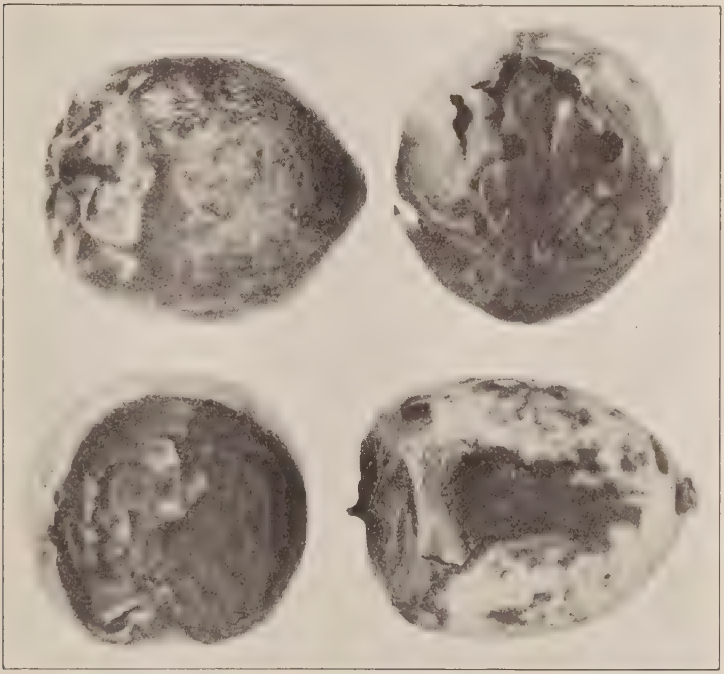

Fig. 7.—Advanced stage of bacteriosis of English walnuts. (Natural size.)

healthy nuts. Ants, flies, and many other insects are attracted to the juice, and it may be that they too further disseminate the bacteria on their mouth parts and feet. See "Insects as Carriers of the Organism," page 30.

The depth of the lesions and the extent to which nuts may be injured by them depends on their age at the time of attack. Nuts attacked at any time before, during, or immediately after the pollination period, almost invariably are completely destroyed or shed from the tree. As the nuts grow larger and shell tissue begins to develop, the disease does not progress as rapidly nor do the nuts fall so readily from the tree.

In its earliest developmental stages, the newly formed shell tissue is easily attacked and destroyed, and the developing kernel within, still in the "milk" or "jelly" stage, is likewise quickly rotted to a black, slimy

mass. A little later, when the shell is harder, it may be perforated and the kernel may be destroyed or at least blackened and shriveled to worthlessness (fig. 9). Finally the shell attains a toughness which makes it impenetrable to the bacteria, but some substance, possibly by-products of

Fig. 8.—Bacteriosis of English walnuts showing drops of the black, slimy sap that oozes from the lesions immediately after irrigation or heavy rain storms. (Natural size.)

the bacteria or even decomposition products from the decayed husk tissue itself, may filter through the shell and produce discoloration or even partial shriveling of that portion of the kernel immediately under the diseased area on the husk. During the last stage of its maturity neither the bacteria nor their by-products can penetrate the shell. At this stage the kernel is not apt to show shriveling or discoloration, but the outside of the shell may be badly stained and the nut rendered a cull because of

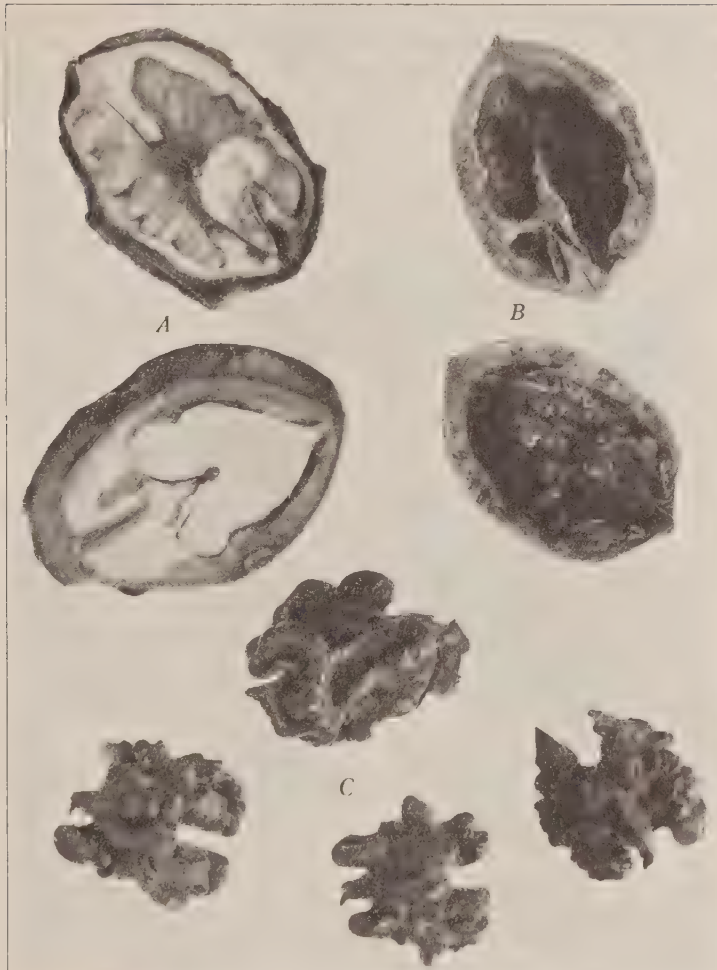

Fig. 9.—Bacteriosis of English walnuts: *A*, two views of healthy walnut meats in cross section; *B*, total destruction of the kernel within the shell by the disease; *C*, kernels attacked later than in *B*. They are shriveled, black, and unfit for food. (Natural size.)

it. No bleach is sufficiently powerful to remove the stain from the shell without injuring the quality of the kernel. Not infrequently much of the rotten husk tissue clings tenaciously to the shell and makes the nut even more unsightly (fig. 10).

The above description is concerned only with the disease in its nat-

ural or uninterrupted progress in infected nuts. There are times, however, when the disease is arrested, and the nut survives the attack. This rarely takes place when the nut is very small, but frequently may be observed when it is more mature. In such cases the nut may continue its development but at harvest time show perforations of the shell, deformity, and other imperfections proportional to the damage done at the time the disease was arrested.

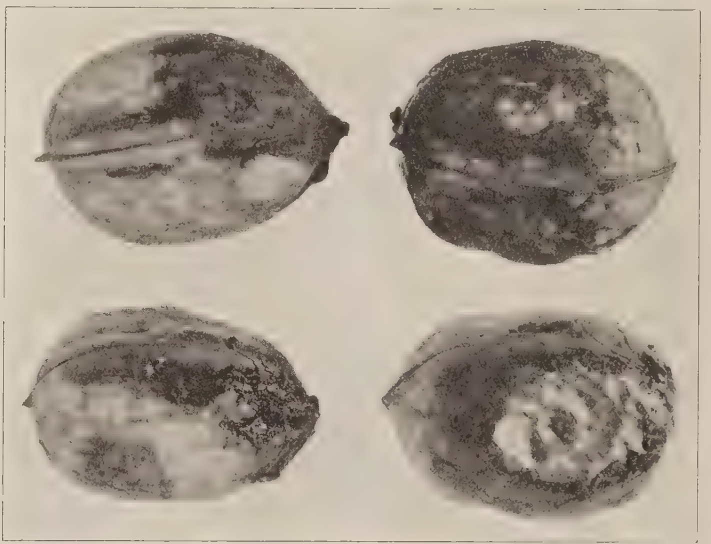

Fig. 10.—Stain produced on the shells of English walnuts by bacteriosis which causes the nuts to be graded as culls regardless of the quality of the kernels. Note the decayed husk tissue adhering to the shell of several of the specimens. (Natural size.)

Infections taking place very late in the season make slow progress as a rule. Spots of varying size are developed on the husk as usual, but generally they tend to be small. These lesions are more or less confined to the outer tissues of the husk and may not even reach the shell. No damage to the nut results from such attacks.

Mere blackening or shriveling of a kernel is not always attributable to the effects of bacteriosis. Many other factors, largely physiological, frequently bring either about. Drought may cause shriveling, and sunburn may cause both darkening and shriveling of the kernels (fig. 11). Sunburn is often mistaken for bacteriosis by growers who have not studied the disease closely. They are easily distinguishable, however. Husk tissue that is severely sunburned is dry and leathery in contradistinction to blighted tissue, which is soft and water-soaked. Also sunburned

husk tissue does not cling to the shell as does tissue affected with blight. There are other dissimilarities but they need not be mentioned here.

Improper harvesting and processing methods can utterly ruin the color of both shell and kernel; to delay husking nuts that have been har-

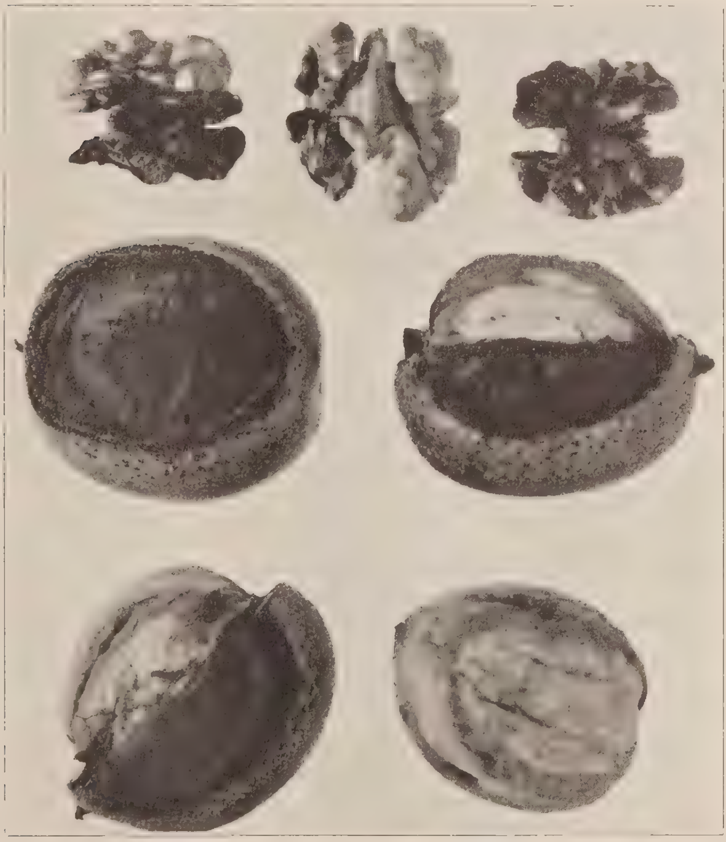

Fig. 11.—Severe sunburn of English walnuts showing the damage done to the husks, shells, and kernels. The circular stripe on the husks and shells is characteristic only of severe burns. (Natural size.)

vested may cause the shells to be stained and the skins of otherwise perfect kernels to turn almost black.

Diseased nuts usually fall of their own accord from the tree. Ordinarily the slightest jar will dislodge them. Occasionally, however, the organism works its way rapidly through the tissue into the stem and kills it before the nut can be shed. In such cases the nut remains hanging

to the branches as a "stick-tight"[16] indefinitely or, at least, until shaken off by wind storms. Infections at the base of the nut near the stem or on the stem itself easily may lead to the production of stick-tights.

Occasionally the disease may pass through the stem of the nut into the base of the twig to which it is attached and cause the development of a small canker there.

On the Catkins.—Apparently the catkins are not as susceptible to the disease as the nuts, but under suitable conditions they too may be attacked. The disease never develops until after the catkins have broken dormancy and are considerably elongated in the spring.

When affected with bacteriosis the individual florets which bear the pollen turn black (fig. 12) and present a somewhat water-soaked and wilted appearance, which contrasts sharply with the green, turgid appearance of healthy florets of the same catkin. A single floret may be affected, or all the florets on one side or at the top or at the bottom of the catkin may show the disease. Similarly the rachis may be attacked at any point along its length. Distortions and deformities in catkins often result from the killing of local areas only (fig. 12).

C. O. Smith (54, 55, 56) has shown that pollen may become infected. It may be that bacteria-laden pollen falling upon the flower parts of the young nuts is responsible for much of the blossom-end infection, but this point has not been proved.

SPECIES OF JUGLANS AFFECTED BY THE DISEASE

Bacteriosis affects the English (Persian) walnut (*Juglans regia* L.) almost exclusively, as far as known. According to C. O. Smith (51, 53, **62**), under suitable conditions, the disease may be induced artificially in eastern or American black walnut (*Juglans nigra* L.), the southern California black (*J. californica* Wat.), and the northern California black (*J. californica* Wat. var. *hindsii* Jepson) by inoculating the tender shoots and leaves with the bacteria by the needle-puncture method. In one instance C. O. Smith (62) noted that bacteriosis had spread naturally from artificially infected leaves of northern California black walnut to nearby leaves on the tree. The writer occasionally has seen natural infections on the leaves of suckers on California blacks topworked to English varieties which were seriously diseased at the time. Ordinarily, even in nurseries where the disease is apt to affect English walnut seedlings severely, it is never seen on black stock of any kind.

The butternut (*Juglans cinerea* L.) and the Japanese walnuts (*J.*

[16] The term "stick-tight" is used also to designate a nut which cannot be separated easily from the husk.

sieboldiana Maxim and *J. sieboldiana* var. *cordiformis* Makino) may also be infected by the needle-puncture method, according to C. O. Smith (62).

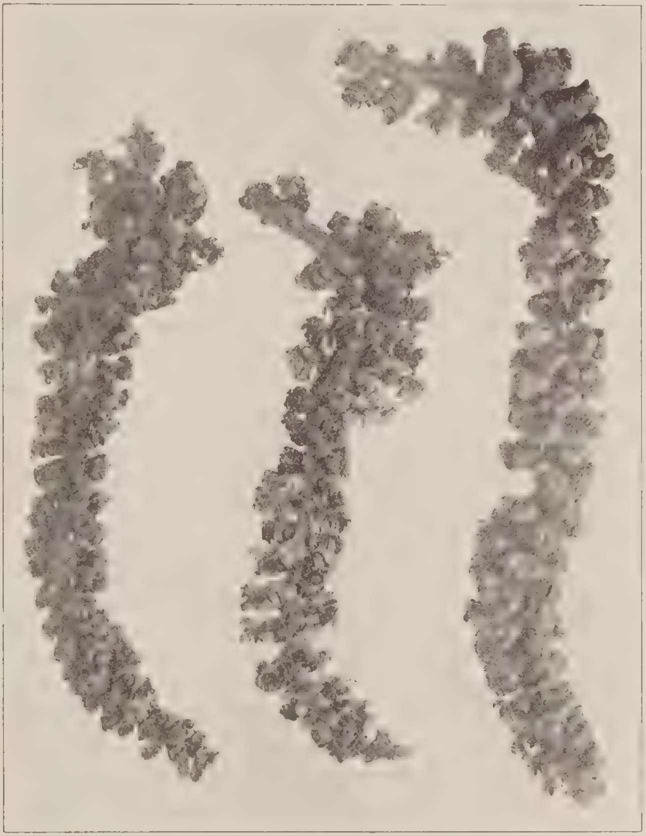

Fig. 12.—Bacteriosis of the catkins of the English walnut. Note the blackening of a local area on the rachis or stem of the catkin on the right. Also note that the healthy florets on the catkins are light in color, the diseased ones are black. (Natural size. Photographed by J. T. Barrett.)

C. O. Smith (41, 53, **62**) has found bacteriosis occurring naturally on leaves of Paradox seedlings (a hybrid of the California black walnut and the English walnut) in the nursery, but never on Royal hybrids (a cross between eastern and California black walnuts). But, as indicated above, they may be infected artificially under suitable conditions.

Commercial Varieties Affected by Bacteriosis.—There is absolutely

no known variety of the English walnut which is immune to bacteriosis and not many which even show any great resistance. A few varieties do show what appears to be a definite resistance to the disease, but the characteristic is traceable to their peculiar habit of foliating late in the spring rather than to any inherent, physiological properties. Thus, the Franquette, a very late variety, frequently escapes the disease in central California, where the annual rains are practically over at the time this variety breaks the bud. Farther north, however, in Oregon, where the climate is much damper, the Franquette crop may be wiped out.

While all commercial varieties and seedling trees may be regarded as subject to attacks of varying severity according to the climatic conditions under which they are grown, the following have been specifically reported as susceptible and discussed in the literature: Bishop (62); Chaberte (73); Chase (62, 89); Concord (54, 62, 89); Ehrhardt (10, 54, 55, 56, 85); El Monte (33, 62, 98); Eureka (1, 10, 23, 54, 55, 56, 89); Franquette (1, 8, 9, 34, 44, 50, 54, 56, 62, 73, 80, 89, 96, 98); Gladys (73); Grove (10); Mayette (34, 44, 50, 56, 73, 89, 96, 98); Meylan (34, 50); Meylannaise (73); Parisienne (73); Payne (10, 64, 65, 89); Placentia (10, 23, 54, 55, 56, 62, 64, 65, 85, 89); Pride of Ventura (62); Prolific (62); Santa Barbara Soft Shell (62); Santa Rosa (62); seedlings (9, 10, 23, 32, 54, 55, 62, 85, 96, 98); Treyve (73); Vourey (73).

While true physiological resistance in any variety is difficult to recognize, it is a very easy matter to see that some individual trees are more susceptible to the disease than others. This applies especially to seedling trees. The degree to which each is affected by bacteriosis varies greatly, but in practically all seedling orchards there is a tree or two so susceptible to attack that it is outstanding. Owners not infrequently put identification marks on such trees and on request can readily point them out.

It is impossible to recommend any one variety as suitable for general planting everywhere. The grower should select the variety best adapted to his locality, taking into account not only its commercial possibilities there but also its probable degree of resistance to bacteriosis under the climatic conditions which prevail in the vicinity. In a broad way, however, he can be guided in making his choice by the time a variety starts growth in the spring. It would be foolish, for instance, to plant such early varieties as the Santa Barbara Soft Shell, Ware's Prolific, Placentia, or Payne in the coastal counties of Oregon where the rainy season persists for months after growth has started in these varieties. From the standpoint of bacteriosis alone these varieties are much more suited to regions farther south, in central or southern California. Many other factors, of course, must be considered in selecting a variety, but a discussion of them is beyond the scope of this bulletin.

THE ORGANISM RESPONSIBLE FOR BACTERIOSIS

Pierce's Description of the Organism.—In his only technical description of the organism which causes walnut bacteriosis, Pierce (42) named it *Pseudomonas juglandis*. In 1905, E. F. Smith (57) changed the name to *Bacterium juglandis* (Pierce) E. F. S., and in 1930, a committee of the Society of American Bacteriologists[17] reclassified it according to a newer and more modern system calling it specifically *Phytomonas juglandis* (Pierce) Bergey *et al* (11).

The following is a verbatim copy of Pierce's original description of the organism and its culture characteristics:

Pseudomonas juglandis, n. sp.—A short, rod-shaped microorganism with rounded ends, actively motile, bearing a single long polar usually wavy flagellum. Length of organism, taken from colony in acid gelatin, set directly from walnut, and stained with gentian violet, 1–2 μ, according to whether the germ has just divided or has elongated but not yet divided. Just before separation a pair of germs will usually average about 2 μ in length. Average breadth of organism about 0.5 μ. Occurs singly or in pairs, and sometimes in shorter or longer chains. Produces a bright chrome-yellow growth on potato and many other media. When growing normally on potato the starch is so acted upon by a diastatic ferment produced by the organism, that it is altered throughout a wide band beyond the margin of the culture of organisms. This band of converted starch may extend 0.5–1 cm or more beyond the margin of the growth of germs, appears white to the eye, fails to show normal starch reaction to iodine, yields marked grape sugar reactions, has an exceedingly sharp and well defined limiting outline, often passing so sharply through a cell as to include only the starch grains on one side of the cell. This broad and distinct ferment band distinguishes this organism at once from *Pseudomonas stewarti* and *P. hyacinthi*, as well as from the more nearly related *P. campestris*, which occasionally forms a weak but much narrower band, and from all other uniflagellate organisms studied. Organism prefers neutral or acid reaction of culture medium, a moderate degree of alkalinity inhibiting growth; it liquefies neutral and acid gelatin. Produces no gas in fermentation tubes of sugar solutions; growth confined to neck and bulb of tube, hence aerobic, no growth under mica plate. Colonies in malic acid potato gelatin and agar circular; at first clear but soon decidedly yellow, margin sharp. This organism is distinguished from *P. campestris*, the most nearly related species of the genus, aside from the characters already assigned, in producing an abundant and bright yellow pigment on the surface of extracts of the leaves of the following plants, while *P. campestris* produces little or no pigment upon such extracts: walnut *(Juglans regia)*, magnolia *(Magnolia macrophylla)*, fig *(Ficus carica)*, castor bean *(Ricinus communis)*, loquat *(Eriobotrya japonica)*.

Since his paper appeared, several workers in this country and abroad have repeated Pierce's laboratory studies and have verified his findings

[17] For a discussion of this newer genus, see: Burkholder, W. H. The genus *Phytomonas*. Phytopath. 20(1):1–23. 1930.

in the main. Doidge (18), C. O. Smith (62), and Wormald (73) have reported additional laboratory studies of the organism. Bergey (11), Elliott (21), and Stapp (66) have given descriptions of the organism and its culture characteristics, largely based upon the work of Pierce and others.

The Effect of Desiccation and Sunlight on the Organism.—C. O. Smith (62) has shown that the organism can withstand desiccation for as long as seventy-three days when kept in the dark but dies after four days' desiccation in the light.

Just how much direct sunlight the organism can stand has not been reported, but it probably will not stand desiccation and direct sunlight in combination for more than an hour, if that long.

Longevity of the Organism in the Soil.—No one has reported isolating the organism from the soil itself. Repeated attempts by the writer over a period of years to isolate the bacteria from the soil under badly diseased trees have failed. Even moist soil rich in the humus of decayed walnut husks found around packing houses failed to yield the organism. Cultures were made from surface soil and from that taken at different levels to a depth of 18 inches.

C. O. Smith (54) found that the organism does not survive long when inoculated in either sterilized or unsterilized soil. Cultures made at short intervals indicated a rapid disappearance of the bacteria starting within 24 hours after the time of inoculation. In sterilized soil the organism lived the longest and could be recovered as long as eighteen days after inoculation, but in unsterilized soil, kept at 20° C, it disappeared in from six to nine days.

Source of the Organism.—Pierce states in most of his papers that the bacteria live over the winter in the dead tissue of the affected shoots and in the old rotten nuts and leaves on the ground. A number of workers have verified his findings on rotten nuts and diseased twigs but not on the leaves. The work of C. O. Smith in this connection is particularly pertinent to California conditions. Smith (53, 54, **62**) isolated the organism from diseased epidermis, wood, and pith of shoots and from rotten nuts hanging in the trees at approximately monthly intervals between the fall and the following spring when the new growth and young nuts had appeared, thus proving such material capable of harboring the organism over the winter.

It is the general opinion of investigators—and there seems to be no reason for doubting it—that the living organisms are washed out of the old lesions on the twigs and decayed nuts by the winter and spring rains and spattered onto the susceptible growing shoots, leaves, and nuts.

More recently Miller (98) has isolated the organism from dead buds. C. O. Smith (53, **54**, 55) isolated the organism from the surfaces of healthy leaf and catkin buds in the early spring before growth had started. It is his belief that the organism is commonly disseminated on the healthy buds of scions. He was able to induce little or no infection by inoculating dormant buds even by severe or extreme methods. Leaf buds inoculated when dormant produced healthy foliage in the spring, and catkin buds produced healthy catkins. But inoculations made after the buds had started to grow were increasingly successful according to the stage of development the new growth had reached at the time the inoculations were made. The deduction to be drawn from this is that the buds or the new growth from them must reach a certain maturity or stage of development before infection can take place.

The Relation of Atmospheric Moisture to Infection.—Probably no outside factor plays so great a role as atmospheric moisture in bringing about infection. That the disease is worse in wet years is universally recognized. Nothing is so conducive to infection as a heavy, protracted rainstorm. But even other forms of precipitation on the susceptible parts such as moisture from fogs, dew, etc., are frequently sufficient to bring about an attack.

In California the greatest loss occurs during the wet months of early spring when the nuts are still small. As the long dry season approaches and the rainfall becomes more scanty, infection decreases. After May it may even be negligible. On the other hand, damp summer fogs and mists frequently prevail along the coast and at times penetrate to the interior valleys where walnuts are grown. In their wake late or secondary infections may follow.

Probable Method of Infection.—The epidermis of the susceptible parts is possessed of a multitude of breathing pores called stomata, which are capable of being opened or closed by the plant according to its physiological requirements. In dry weather, particularly when water is scarce, the breathing pores are apt to be closed, or nearly so, to prevent an excessive loss of moisture. In wet weather, and especially after irrigations, the breathing pores are apt to be wide open to facilitate the passage of excess sap out of the plant tissues. While no one has reported actually seeing the walnut-blight organism enter a breathing pore it is generally accepted that they do. Considering the fact that the organisms are motile and able to swim relatively long distances in water it does not seem unreasonable to suppose that many of them find their way through the open pores. Wounds and abrasions also offer a means of easy entrance to the inner tissue. Once within, an ample food supply permits of the multiplication and destructive activities of the parasite.

That the organism can attack the susceptible parts readily through the medium of water is evidenced by the ease with which infections can be induced artificially with it. Bacteria from a pure culture (or the juice expressed from the rotten nuts) when added to water and atomized onto healthy nuts will attack them. Diseased spots may become visible as soon as two or three weeks after atomizing and steadily increase in number until there are hundreds of them on individual nuts at the end of a month. (C. O. Smith, 56, 62, and author's observations.) C. O. Smith (62) also found that infection was slight when the fruit was atomized in warm sunny weather. This bears out the field observations of many, that infection does not take place so readily during brief, light showers or foggy spells when the water is quickly evaporated from the surface of susceptible parts.

Mechanical Injuries.—The simplest, quickest, and surest way to produce bacteriosis experimentally is to dip a needle in a culture of the organism and prick the epidermis of any susceptible part such as the leaves, young shoots, catkins, or nuts with it. The bacteria introduced into the wound quickly multiply, and in about nine days or longer, according to external conditions, the characteristic rot appears. It stands to reason that any mechanical injury to the susceptible parts such as an abrasion, limb puncture, scratch, etc., may give rise to the disease if by any chance the organism should be introduced into the wound. Many infections clearly take place in this way.

Insects as Carriers of the Organism.—C. O. Smith (62) proved experimentally that insects may carry the germs on their feet and mouth parts, particularly when they have walked through or fed upon the bacterial exudate which so frequently oozes from the decayed spots. (See fig. 8, p. 20.) To what extent they spread the disease by tracking the organism over healthy susceptible tissue is not known, but it is conceivable that some infection follows the spread of the organism in this way, especially in wet weather. Organisms tracked onto dry, uninjured epidermis exposed to direct sunlight, probably not only are unable to make an attack but are likely to be killed by the disinfectant action of the sun.

The walnut aphid (*Chromaphis juglandicola* Kalt.) has been suspected of disseminating the blight bacteria. The insect confines its attacks, however, almost entirely to the leaves, which ordinarily are little affected by the disease. It does not seem probable, therefore, that aphids are responsible for the spread of bacteriosis in the nuts to any great extent.

In 1927 an experiment was undertaken to determine whether the disease could be reduced in amount by controlling the walnut aphids. A block of sixteen trees in the Anderson-Barngrover Ranch Company's

orchard at Linden was sprayed for the first time just as the new growth and catkins were beginning to appear, and then at frequent intervals, never exceeding one month, throughout the balance of the season with an insecticide of the following formula:

Black Leaf 40 (40 per cent nicotine sulfate)	2 pounds
Caustic soda	1 pound
Water	200 gallons

Additional applications of 2 per cent nicotine dust were given when the balance of the orchard was dusted for aphid control. The control of aphids was excellent in the experimental plot, poor in the trees outside of it. But the crop on the sprayed trees was severely attacked by bacteriosis regardless of the control of the aphids, and to the eye presented no less disease than that on unsprayed trees. The experiment described is admittedly limited, but the results would seem to indicate that the control of aphids at least does not necessarily effect an appreciable control of the disease.

Insects which bite or bore into the young shoots or nuts may enable the disease to get a foothold. Not infrequently bacteriosis starts at holes in the nuts made by the husk maggot and the larvae of the codling moth, two serious pests of the walnut in certain parts of California.

LOSSES DUE TO BACTERIOSIS IN CALIFORNIA

It is impossible to give the loss occasioned the state of California by bacteriosis in exact figures. All authorities are agreed, however, that the loss of crop due to it far exceeds that of all other walnut diseases put together. Growers' estimates of losses are apt to be too low rather than too high, because usually they are made late in the season when the diseased nuts hanging in the trees or lying on the ground are clearly evident to the eye. The greatest loss of crop, however, ordinarily occurs very early in the season when the nuts are still very small. Such affected nuts fall, quickly disappear from sight, and the quantity of them is generally underestimated as a consequence.

Only very general estimates and fragmentary observations of seasonal losses in the more important walnut districts of California are available. Often these are contradictory. Twenty years ago C. O. Smith (62) pointed out that although the walnut acreage at that time in southern California had multiplied many times during the previous decade, the total walnut crop of the state had not increased during the same period. He attributed this largely to the ever increasing destructivity and spread of bacteriosis. The disease is no less serious today than it was

then, consequently the loss to the state since it was first introduced must have run well into the millions of dollars.

C. O. Smith (62) estimated the average loss occasioned by bacteriosis during the ten years previous to the time he wrote at 50 per cent.

He points out that in individual years the crop may be so badly attacked that not a single healthy nut remains at harvest. The writer frequently has made similar observations. Such losses must be regarded as 100 per cent. On the other hand bacteriosis may be present in some orchards year after year to no greater extent than necessary to give the crop a desirable thinning. But many orchards likewise are visited year after year by the disease in a distinctly more severe form. One grower in Santa Clara County whose orchard is well known for its fine trees of mature age told the writer that he never yet had learned their full bearing capacity because of the consistent annual losses occasioned by bacteriosis ever since they had come into bearing. This situation probably prevails in many other orchards.

Growers in the counties bordering on San Francisco Bay as well as in the interior in San Joaquin County readily agree that in years favorable to bacteriosis their losses vary from 50 to 80 per cent. In all of these localities the loss may be as little as 10 per cent when climatic conditions are unfavorable to the disease.

In Santa Barbara County many orchards have been observed in which the loss could be estimated conservatively at 75 per cent. Mr. Hooper, formerly Walnut Extension Specialist of the University, believes the average loss in this same region over a period of years to be about 25 per cent.

Numerous orchards have been visited in Los Angeles County in which the loss could be estimated conservatively at 50 per cent. Observers in Orange, Los Angeles, and other southern counties, are not inclined to regard the average annual loss as high as C. O. Smith did in these same localities twenty years ago. This is not at all improbable, considering the drought that has prevailed for a decade in the state and in southern California in particular.

The losses that have been described thus far may be called direct losses. They are concerned merely with the extent to which bacteriosis may destroy the crop in the trees. Indirect losses, less obvious, may be traced to bacteriosis also. Probably no factor has contributed more than bacteriosis to making necessary the complicated routine of the modern walnut packing-house. To separate the good nuts from the diseased (blanks or blows), specially designed vacuum machines must be employed. Also, otherwise good nuts rendered culls because of blight stain

on the shells must be sorted out by hand. To accomplish this the crop must be passed along moving belts in front of workers who examine each nut and remove the blemished ones by hand. The cost of machinery and labor annually employed throughout California in the production of a standard merchantable pack of walnuts free from bacteriosis or its effects is very great. Similarly the cost of converting the blight culls into useful by-products is no small item.

CONTROL EXPERIMENTS

METHODS OF CONDUCTING THE EXPERIMENTS

The Plan of the Experiments.—Because no previous experiments reported in the literature included the application of sprays during the active growing season of the walnut, it was considered advisable to try to effect a control of the disease with spring and summer sprays. Also, since the literature had consistently reported nothing but failure with dormant or winter sprays it was decided to exclude them from the experiments, for the time-being at least. Lastly, because the period of susceptibility of the walnut is an exceedingly long one, lasting from the time the nut first appears in the spring until it is ripe and ready to drop from the husk in autumn, it seemed improbable that any spray schedule could succeed that did not include the use of several applications of any given material to the same trees, since no one application of spray or its effects lasts indefinitely.

To test out the above ideas a system of moving plots was devised to permit the application of any spray solution to a constant unit of trees in single or multiple applications and in gradually increasing or decreasing numbers over any given period of time with a minimum of labor and trouble. Figure 13 shows a diagram of a moving plot.

According to the plan, 40 trees were sprayed with a given spray solution at definite intervals, but with each additional application of spray the entire plot was moved forward so as to include 10 new unsprayed trees at the front while 10 previously sprayed trees were dropped from the rear. Thus as a result of overlapping, a series of definite, smaller blocks of 10 trees were created which were sprayed one, two, three, and four times each; also blocks of 10 trees, each of which received all sprays but the first, all but the second, and none but the fourth giving a total of 7 blocks of 10 trees each, or a total of 70 trees to each moving plot treated with any one spray material.

Check plots of unsprayed trees, never less than 10 in number, invariably were left at the front and rear end of any moving plot for the

sake of comparison. Also, any one entire moving plot sprayed with a given solution always was separated from another sprayed with a different one by at least one row of trees to avoid the possible influence of wind-blown spray from one plot on the other. Usually as many as three rows separated the moving plots and in some instances many more, and these unsprayed trees also served as checks.

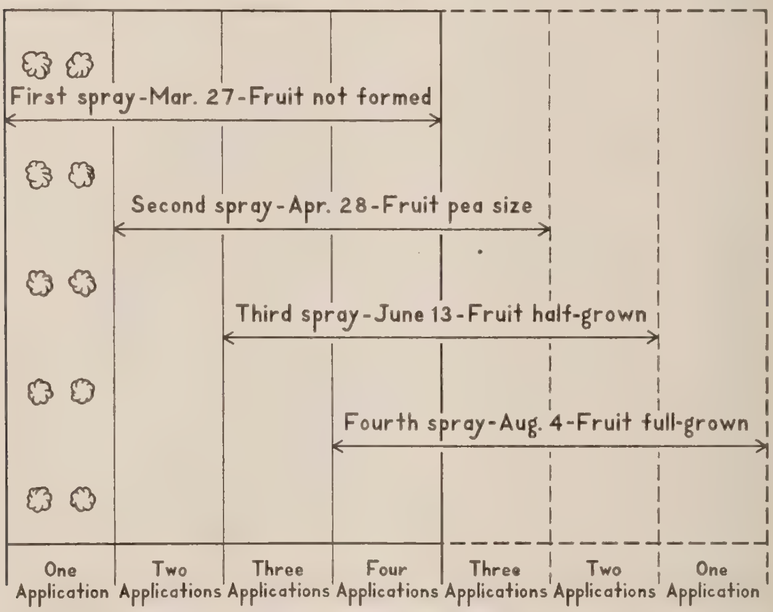

Fig. 13.—Diagram of a typical moving spray plot. This type of spray plot possesses many advantages in spraying walnut trees experimentally for the control of bacteriosis.

Figure 13 shows the spray schedule followed the first year. The first application of spray was made when the buds were bursting and the first new growth had appeared but before any appreciable number of young nuts were exposed. The second application was made when the young nuts had reached the size of peas, the third when the nuts were half-grown, and the fourth when full-grown. In subsequent years various modifications in this schedule were made until a satisfactory one was found. See "How to Spray to Control Bacteriosis," p. 61, for the spray schedule now recommended to growers.

Where the Experiments Were Conducted.—The spraying experiments were conducted at widely separated points in California on both seedling and budded varieties. Most of the work on budded varieties was done in San Joaquin County near Linden, whereas the work on seed-

lings was done largely in southern California in numerous orchards scattered through Santa Barbara, Los Angeles, and Orange counties. Cooperative work with H. P. Barss, Oregon State College, who sought assistance in combating the disease in Oregon, was undertaken the third year of the experiments and certain interesting data were received from him.

How the Sprays Were Applied.—The sprayings were made with a modern spray rig of 400-gallon capacity. The rig was equipped with 12-inch iron tires shrunk to the wheels, a feature which made it possible to negotiate soft wet ground in the spring with a full load of spray. An extension tower from the top of which very tall trees could be sprayed effectively was also provided.

A constant pressure of 500 pounds was maintained for each application made except on small trees, when the pressure was reduced to meet the circumstances. For trees of moderate size, ordinary spray guns were used, but for large trees, shade-tree guns and the Spencer walnut-tree gun were frequently employed. No. 8 and No. 9 tips were used in the Spencer guns, but smaller ones (Nos. 6 and 7) may be obtained for work on smaller trees.

Spray Materials Used.—Since practically all of the various materials and combinations of materials used in the experiments proved utterly valueless in the control of bacteriosis and often harmful to the trees as well, a detailed discussion of them would be of little value at this point. See the "List of Materials Tried with Doubtful, Limited, or Unfavorable Results," p. 77. Those materials which gave any appreciable benefits are discussed under the section entitled "Results Obtained Experimentally with Sprays," p. 36.

Spray Terminology.—The following terms have been used to designate the time when the sprays were applied or the size of the nuts when they were sprayed. A "pre-bloom spray" is one applied when the buds are bursting and some of the new growth has developed but when few or none of the nuts have appeared. This stage of development in the trees is referred to as the "pre-bloom stage." A "post-bloom spray" is one applied when the flowers at the ends of the young nuts have faded and turned brown. This stage of development is referred to as the "post-bloom stage." The terms "pea stage" and "olive stage" indicate rather loosely that the young nuts have reached the size of ordinary peas or olives. The terms "half grown" and "full grown" also refer to the size of the developing nuts in the trees.

Methods of Determining the Extent of Control.—The extent of the control afforded by the different materials used was determined by: (1) comparing the count of diseased nuts in or under sprayed and un-

sprayed trees; (2) comparing the weight of crop from sprayed and unsprayed trees; (3) estimating the extent of control and determining the general effects of the treatments by making personal observations. None of these methods is without fault in determining the extent of disease control in any economic plant, and each is even more faulty when applied to walnuts. For this reason only control data that show the benefits of the spray without the necessity of resorting to statistical methods to prove the point are included in the tables. Wherever possible weights and counts were taken in the same orchard, and in virtually every instance the benefits afforded by the spray were sufficient to be readily apparent on sight alone. For a more complete discussion of the problems met with in determining the amount of control see "Difficulties Involved in Determining Control of Bacteriosis," page 51.

Quality, trade sizes, and grades were determined after the method of the California Walnut Growers Association.[18]

RESULTS OBTAINED EXPERIMENTALLY WITH SPRAYS

Even before the season was very far advanced, in the first year of the experiments, it was strikingly evident that control in varying amounts had been obtained with each of three copper-containing materials, namely, bordeaux, basic copper acetate, and ammoniacal copper carbonate. Bordeaux gave the best results of all, and after several years' trial the basic copper acetate and ammoniacal copper carbonate were dropped from the experiments. See "List of Chemicals and Spray Materials Tried with Doubtful, Limited, or Unfavorable Results," p. 77, for a further discussion of them.

Bordeaux 8–4–50 the Most Satisfactory Spray for Control of Bacteriosis.—Many bordeaux formulas, yielding acid, neutral, and excessively alkaline mixtures, were tried in the course of the experiments. The 8–4–50 formula proved superior to all others, and the control data presented in the tables of this paper were derived almost exclusively from experimental use of spray prepared with it. Weaker mixtures pre-

[18] To determine quality at least three random samples of 100 nuts each from each of the sprayed plots were measured and graded for size, also cracked and tested for color, condition of the kernels, etc., and an average taken of the lot. Measurement of sizes invariably was made with the special device used by inspectors of the Association.

The trade sizes are Large, Fancy, and Baby. Jumbo is an extra-large size no longer distinguished from Large by the California Walnut Growers Association.

The Diamond grade is the best pack of the California Walnut Growers Association. The second-grade pack is known as Emerald, and California is third. Since the qualifications of each grade have fluctuated somewhat in the past and may again in the future, no attempt is made here to define them. The grades are based, however, on the color, size, and condition of both shells and kernels.

pared with ingredients in this same ratio, even bordeaux 4–2–50, often showed distinct control value but were inferior to the stronger spray.

In the 8–4–50 formula the lime is cut to one-half the amount of bluestone used instead of the pound-for-pound ratio generally employed in making bordeaux spray. The amount of lime used is still distinctly in excess of the amount necessary to neutralize all of the bluestone, however. Several advantages are offered by this formula: the spray is distinctly alkaline, and alkaline bordeaux is less toxic or injurious in its action on tender walnut foliage than the acid or neutral mixture. The addition of more lime than that recommended in no way obviates spray burn of walnut foliage when climatic conditions are conducive to it. See "Spray Burn and Other Undesirable Effects," page 69. Bordeaux of the formula recommended also is of more gelatinous consistency and adheres better than one containing a greater excess of lime, and the spray residue left on the foliage is less opaque and impermeable to light—an important point. Finally its maximum benefits are probably obtained more quickly than when bordeaux with a greater excess of lime is used; certain bordeaux chemists are of the opinion that the greater the excess of lime present the slower the disinfectant action of the spray. No great excess of lime beyond the margin of safety for the average grower is contained in bordeaux 8–4–50. See "The Preparation of Bordeaux Spray," p. 71, for a simple method of preparing it.

The Pre-Bloom Spray.—Because the results first obtained in 1927 and substantiated experimentally every year thereafter clearly showed that the strategic period for securing the maximum control with any one spray is during the pre-bloom stage, attention is called to the fact that a pre-bloom spray invariably was given in each experiment recorded in the various tables and observational data that follow.

Control Obtained with Bordeaux 8–4–50 as Indicated by Counts.—In table 1, the figures represent the extent of control obtained with bordeaux 8–4–50 as indicated by count of diseased and healthy nuts in or under sprayed and unsprayed trees. In several of the orchards two or more applications of spray were given.

The counts of diseased nuts in sprayed and unsprayed trees as shown in table 1 indicate a striking control of the disease in most instances.

Control Obtained With One Application of Bordeaux 8–4–50 as Indicated by Weights.—In table 2 the control obtained with a single spray as indicated by a comparison of weight of crop from sprayed and unsprayed trees is shown. The spray was applied in the pre-bloom stage.

In each experiment cited in table 2 the sprayed and unsprayed plots were immediately contiguous, the trees were of the same size, age, and variety, and were subjected to similar growing conditions.

TABLE 1

THE EXTENT OF CONTROL INDICATED BY COUNTS OF DISEASED AND HEALTHY NUTS IN OR UNDER SPRAYED AND UNSPRAYED TREES

Grower	Year	Trees*: Variety	Trees*: Age	Trees*: Number	Treatment: Spray	Treatment: Date	Treatment: Size of nuts when sprayed	Date of nut count	Total nuts counted	Location of the nuts when counted	Blighted nuts: Total	Blighted nuts: Average per tree	Blighted nuts: Per cent
Bishop Ranch, Goleta, California	1930	Seedlings	Old	10	Bordeaux 8-4-50	Apr. 22 June 9†	Pre-bloom, Half-grown	Aug. 12	2,900	In trees	138	13.8	4.75
				10	Unsprayed	....	....	Aug. 12	3,563	In trees	1,618	161.8	45.43
C. E. Bainbridge, Kenwood, California	1928	Concord	14 yrs.	8	Bordeaux 8-4-50	....	Pre-bloom stage	Late summer	Negligible	On ground	....	Negligible or none	....
				5	Unsprayed	....	....	Late summer	840	On ground	....	168	....
R. Forbis,‡ Lilley, Oregon	1929	Franquette	13 yrs.	24	Bordeaux 8-4-50	May 21	Pre-bloom stage	July 10	2,122	In trees	176	7.3	8.3
				23	Unsprayed	....	....	July 10	2,390	In trees	1,063	46.2	44.4
J. O. Holt,‡ Eugene, Oregon	1929	Franquette	18 yrs.	10	Bordeaux 8-4-50	May 21 June 21†	Pre-bloom stage Pea size	July	927	In trees	5	0.5	0.5
				10	Unsprayed	....	....	July	1,875	In trees	222	22.2	11.8

* The blocks of sprayed and unsprayed trees bracketed together were immediately adjacent to each other, of the same age and variety, and outside of the spray treatment subjected to conditions as identical as it was possible to secure.

† Second spray on same block.

‡ Data furnished by H. P. Barss of the Oregon State College, Corvallis, Oregon. Crop weights failed to substantiate the excellent controls indicated by the counts in these two orchards. See "Difficulties Involved in Determining Control of Bacteriosis," p. 51 for possible explanations.

TABLE 1—*(Concluded)*

Grower	Year	Trees*			Treatment			Date of nut count	Total nuts counted	Location of the nuts when counted	Blighted nuts		
		Variety	Age	Number	Spray	Date	Size of nuts when sprayed				Total	Average per tree	Per cent
Walter Stevens, San Jose, California	1930	Payne	10 yrs.	21	Bordeaux 8-4-50	March May †	Pre-bloom stage Olive size	July 11	....	On ground	362	17	....
				6	Unsprayed	....	....	July 11	....	On ground	553	92	....
Hunt Bros. Packing Corporation, Linden, California	1930	Payne	14 yrs.	7	Bordeaux 8-4-50	Mar. 27 Apr. 20†	Pre-bloom stage Post-bloom	July 1	....	On ground	120	17	....
				7	Unsprayed	....	....	July 1	....	On ground	1,350	236	....
J. M. Colley, Santa Paula, California	1932	Seedlings	30 yrs.	7	Bordeaux 8-4-50	....	Pre-bloom stage Olive size†	Aug. 5	....	On ground	477	80	....
				8	Unsprayed	....	....	Aug. 5	....	On ground	2,677	335	....
E. A. Smith, Concord, California	1932	Payne	9 yrs.	12	Bordeaux 6-3-50 Bordeaux 8-4-50† Bordeaux 8-4-50¶	Mar. 20 May 8 June 3	Pre-bloom stage Large olive size $\frac{3}{4}$-grown	Late July	....	On ground	1,031	85.9	....
				12	Unsprayed	....	....	Late July	....	On ground	2,524	210.3	....

* The blocks of sprayed and unsprayed trees bracketed together were immediately adjacent to each other, of the same age and variety, and outside of the spray treatment subjected to conditions as identical as it was possible to secure.

† Second spray on same block.

¶ Third spray on same block.

TABLE 2

THE EXTENT OF CONTROL OBTAINED WITH A PRE-BLOOM SPRAY OF BORDEAUX 8–4–50 AS INDICATED BY A COMPARISON OF THE NET WEIGHTS OF NUTS FROM SPRAYED AND UNSPRAYED TREES

Grower	Year	Trees*			Treatment	Total yield	Average yield per tree	Net gain per tree
		Variety	Age	Number				
						lbs.	lbs.	lbs.
Russel Rowe, Goleta, California	1930	Seedlings	Old	12	Bordeaux 8-4-50 +1½ per cent San Jose Summer Oil	1,644	137	38
				12	Unsprayed	1,183	99	
Bishop Ranch, Corona del Mar, Plot 1. Goleta, California	1929	Seedlings	Old	24	Bordeaux 8-4-50	4,054	169	23
				24	Unsprayed	3,492	146	
Bishop Ranch, Corona del Mar, Plot 2. Goleta, California	1929	Seedlings	Old	12	Bordeaux 8-4-50	1,182	99	19
				29	Unsprayed	958	80	
E. U. Leh, Concord, California	1930	Payne	5-year grafts on 10-year trees	25	Bordeaux 8-4-50	552	22	8
				25	Unsprayed	351	14	
Mrs. J. G. Miller, Linden, California	1929	Payne	Old	8	Acid bordeaux	720	90	26
				16	Unsprayed	1,020	64	
C. E. Bainbridge, Kenwood, California	1928	Concord	14 years	8	Bordeaux 8-4-50	488	61	20
				5	Unsprayed	205	41	
G. C. Bailey,† Wilbur, Oregon	1929	Franquette	19 years	17	Bordeaux 8-4-50	1,326	78	36
				17	Unsprayed	714	42	
Anderson-Barngrover Ranch Co. Orchard, Linden, California	1927	Payne	7-year grafts on 10-year trees	10	Bordeaux 8-4-50	227	23	6
				10	Unsprayed	169	17	
Bowman-Kuhn Ranch‡, San Jose, California	1930	Mayette	20 years	6	Bordeaux 8-4-50	570	95	42
				6	Unsprayed	318	53	
Raymond Miller‡ Linden, California	1931	Payne	16 years	5	Bordeaux 8-4-50	761	152	65
				5	Unsprayed	437	87	
Mrs. J. G. Miller,‡ Linden, California	1931	Payne	20 years	6	Bordeaux 8-4-50	827	138	40
				6	Unsprayed	588	98	

* The blocks of sprayed and unsprayed trees bracketed together were immediately adjacent to each other, of the same age and variety, and outside of the spray treatment subjected to conditions as identical as it was possible to secure.

† Data submitted by H. P. Barss, Oregon State College, Corvallis, Oregon.

‡ A large acreage was sprayed in this orchard with the same results indicated by the smaller number of trees in the table.

A comparison of crop weights from sprayed and unsprayed trees as shown in table 2 indicates a noteworthy control of the disease in most instances with one application of spray.

The acid bordeaux which gave the control listed in Mrs. Miller's orchard at Linden was applied experimentally by the writer. This type of bordeaux is further discussed under the heading, "List of Materials Tried with Limited, Doubtful, or Unfavorable Results," on page 77.

Control Obtained with Two Applications of Bordeaux 8–4–50 as Indicated by Weights.—In the preceding section the results obtained with a single spray applied during the pre-bloom stage are shown. In each case the control has been definite, in many instances striking.

In table 3 the cumulative effect of two sprays is shown. In each experiment two plots lying side by side received a spray during the pre-bloom stage. Later, as indicated in the table, one of the plots received a second application of the spray at the same strength. At harvest the yield of nuts from each sprayed plot was compared with that from an adjoining block of unsprayed trees. The beneficial effects derived from each individual application of spray are unmistakable.

In table 3 it may be noted that the first spray seemingly effected little control of the disease in Dr. Campbell's orchard. As a matter of fact the control afforded by the first spray was great. The beneficial effects of the first application were gradually lost in this plot, however, when no additional sprays were applied to protect the crop.

In table 4 additional figures are given which show the control obtained with two sprays. In each case the first spray was given in the pre-bloom stage and the second after the nuts had set. No attempt was made to determine the benefits of each individual spray as was done in the orchards cited in table 3.

Control Obtained with Multiple Sprays of Bordeaux 8–4–50.—An attempt was made to determine whether multiple sprays, namely, several applications of a given spray to the same trees, would effect a better control of bacteriosis than one spray alone. In table 3 the comparative benefits of one and two sprays are shown. Thus far it has been impossible to show in figures the additional value of a third or fourth spray in fighting the disease. This is because the requirements for obtaining comparable results in such an experiment are so exacting that it is practically impossible to find them in any one orchard. Fluctuation in the size and general health of the trees as well as in the size of the crop set at different parts of the orchard, the result of uncertain causes, likewise the irregularity with which the disease itself appears, complicate the problem of securing reliable figures to show the relative benefits afforded by more than two sprays. Yet observations made in the course of many experiments

TABLE 3

COMPARISON OF THE WEIGHTS OF NUTS FROM UNSPRAYED TREES, AND FROM TREES SPRAYED DURING THE PRE-BLOOM STAGE, AND FROM TREES SPRAYED TWICE INCLUDING THE FIRST SPRAY MENTIONED

Grower	Year	Trees*			Treatment		Total yield	Average yield per tree	Net gain per tree
		Variety	Age	Number	Spray	Time of application			
							pounds	*pounds*	*pounds*
Dr. E. O. Campbell, Goleta, California	1929	Seedlings	30 yrs.	12	Unsprayed	....	472	39	
				12	Bordeaux 8-4-50	Pre-bloom stage only	504	42	3
				12	Bordeaux 8-4-50	Pre-bloom stage and on June 1	712	59	20
Bishop Ranch, Glen Annie, Goleta, California	1930	Seedlings	Old	26	Unsprayed	....	998	35	
				9	Bordeaux 8-4-50	Pre-bloom stage only	470	52	17
				10	Bordeaux 8-4-50	Pre-bloom stage and on June 9	664	64	29
Bowman-Kuhn Ranch, San Jose, California	1929	Payne	Mature	6	Unsprayed	....	384	64	
				6	Bordeaux 8-4-50	Pre-bloom stage only	528	88	24
				6	Bordeaux 8-4-50	Pre-bloom stage and in July	600	100	36

* The blocks of sprayed and unsprayed trees bracketed together were immediately adjacent to each other, of the same age and variety, and outside of the spray treatment subjected to conditions as identical as it was possible to secure.

TABLE 4

COMPARISON OF THE WEIGHTS OF NUTS FROM UNSPRAYED TREES AND TREES SPRAYED TWICE, WITHOUT CONSIDERATION OF THE INDIVIDUAL BENEFITS AFFORDED BY EITHER SPRAY

Grower	Year	Trees*			Treatment		Total yield	Average yield per tree	Net gain per tree
		Variety	Age	Number	Spray	Time of application			
							pounds	*pounds*	*pounds*
Visalia Orchard Co., Visalia, California	1929	Payne	10 yrs.	19	Bordeaux 8-4-50	Pre-bloom and post-bloom stages	2,244	118	19
				19	Unsprayed	....	1,885	99	....
Hunt Bros. Packing Corporation, Linden, California	1930	Payne	14 yrs.	7	Bordeaux 8-4-50	Pre-bloom and post-bloom stages	1,036	148	37
				6	Unsprayed	....	664	111	....
Bishop Ranch, Corona del Mar, Goleta, California	1931	Seedlings	Old	23	Bordeaux 8-4-50	Pre-bloom and post-bloom stages	1,243	54	21
				19	Unsprayed	....	623	33	....

* The blocks of sprayed and unsprayed trees bracketed together were immediately adjacent to each other, of the same age and variety, and outside of the spray treatment subjected to conditions as identical as it was possible to secure.

designed to show the value of multiple sprays frequently seemed to show that each additional application of spray given at the right time afforded a material reduction in the amount of the disease. In the Anderson-Barngrover Ranch Company's orchard at Linden where much work with multiple sprays was done, the relative control of bacteriosis afforded by three and four applications of bordeaux to the same trees appeared to be much greater than that afforded by one or two; there were fewer diseased nuts in or under trees receiving the benefits of numerous sprays than in or under those sprayed only once. The great fluctuation in the size and general condition of the trees, however, made it impossible to show this difference in figures of any kind.

Control Obtained With Bordeaux 8–4–50 as Indicated by Personal Observations.—The following data are almost wholly observational and not often supported by figures. Such data admittedly have the least value of all and have been used here only when striking in character. Much of the information has been presented by growers who were enthusiastic about the results obtained.

In 1928, Mr. D. Chisholm of Windsor, California, sprayed two long rows of old seedling walnut trees which line the entrance drive to his apple orchard with bordeaux 8–4–50 during the pre-bloom stage. Part of the trees were sprayed a second time with the same spray after the nuts had set. All of the trees had been severely attacked by bacteriosis year after year previous to the experiment. Scattered among the apple trees are walnut replants of various ages and sizes. These alone were left unsprayed. When the writer visited the orchard before harvest, the unsprayed trees were so severely attacked by the disease, that the crop was virtually destroyed in all of them. Under one unsprayed tree the entire crop lay rotting on the ground. All of the sprayed trees, on the other hand, bore a splendid crop.

The control was visibly greater in the trees sprayed twice than in those sprayed only once. Unfortunately neither weights nor counts were made. Mr. Chisholm enthusiastically expressed his satisfaction with the results obtained.

In 1928 and 1929, Mr. Donald Nye of Healdsburg, California, sprayed his sixteen or seventeen-year-old Franquette walnuts with bordeaux 8–4–50 during the pre-bloom stage. An average of only 10 gallons per tree was used, which is a very small quantity for trees of that age. At harvest when the nuts had been shaken down he examined all that lay in a straight strip under the trees. The results are shown in table 5. In 1928, Mr. Nye estimated the crop on the sprayed trees to be three times as great as that on unsprayed trees.

In 1929, Mr. Raymond Miller at Linden, California, sprayed a large block of Payne walnuts with bordeaux 8–4–50 during the pre-bloom stage. Mr. Miller's mother, Mrs. J. G. Miller, owns a similar orchard immediately across the Waterloo road from her son's. This orchard was not sprayed. Both orchards are about eighteen years of age. In late summer Mr. and Mrs. Miller sent for the writer to observe the extent to which

TABLE 5

EXTENT OF CONTROL OBTAINED IN MR. DONALD NYE'S ORCHARD AT HEALDSBURG, CALIFORNIA AS INDICATED BY COUNTS

Year	Treatment	Total nuts counted	Per cent diseased
1928	Sprayed	500	2
	Unsprayed	500	28
1929	Sprayed	500	30
	Unsprayed	500	43

TABLE 6

COUNT OF DISEASED NUTS AND WEIGHT OF GOOD NUTS FROM ONE SPRAYED AND ONE UNSPRAYED TREE OPPOSITE EACH OTHER IN THE ORCHARDS OWNED BY MRS. J. G. MILLER AND MR. RAYMOND MILLER

Treatment	Stage when treated	Count of diseased nuts on ground before harvest	Weight of good nuts harvested	Net gain in favor of spray
			pounds	*pounds*
Bordeaux 8-4-50+2 per cent Volck oil	Pre-bloom	9	167	77
Unsprayed	....	930	90	....

the disease had affected the crop in the two orchards. The ground under the unsprayed trees in Mrs. Miller's orchard was literally covered with blighted nuts, whereas under Mr. Miller's sprayed trees the number was negligible. Two trees, opposite each other, one in Mrs. Miller's orchard and the other in Mr. Miller's orchard were selected as representative of the situation in the two orchards. Counts of diseased nuts on the ground under each tree were made before harvest. The weight of crop from each tree was also taken. The results are shown in table 6.

In 1930, Mr. J. F. Treat, Jr., in charge of the Hunt Brothers Packing Company's walnut orchard at Linden, sprayed a block of Payne walnuts experimentally. On the way to the Payne trees, the spray rig was stopped to spray one fourteen-year-old Eureka tree in a row of 7 trees. The tree was sprayed first during the pre-bloom stage and again when the nuts

were about the size of peas and the flowers had faded. All trees in the row had been affected severely by the disease in previous years. The control obtained was striking. A count of the blighted nuts on the ground under the 6 unsprayed trees and 1 sprayed tree was made in July. Weights were taken at harvest. The results are shown in table 7.

TABLE 7

Count and Weight of Diseased and Healthy Nuts from 1 Sprayed and 6 Unsprayed Trees in the Hunt Brothers Packing Company Orchard at Linden, California, in 1930

Treatment	Stage when treated	Number of trees	Count of diseased nuts on ground		Weight of nuts harvested	
			Total	Average per tree	Total	Average per tree
					pounds	*pounds*
Bordeaux 8-4-50	Pre-bloom and post-bloom stages	1	21	21	253	253
Unsprayed		6	1,886	318	480	80

TABLE 8

Annual Yield of Nuts in Pounds from 76 Payne Walnut Trees in the Hunt Brothers Orchard Previous to and Including 1930, the Year They Were Sprayed for the First Time

Year	Treatment	Yield	Year	Treatment	Yield
		pounds			*pounds*
1923	Unsprayed	2,295	1927	Unsprayed	6,200
1924	Unsprayed	3,124	1928	Unsprayed	3,600
1925	Unsprayed	2,759	1929	Unsprayed	3,639
1926	Unsprayed	695	1930	*Sprayed*	*10,886*

In 1930 Mr. Treat also sprayed a block of 76 Payne walnuts in the Hunt Brothers Orchard for the first time. These trees were planted in 1916–1918. Bacteriosis had destroyed much of the crop year after year previous to the time the trees were sprayed. Before harvest, when the writer visited the orchard, there were very few blighted nuts either in the trees or on the ground. The weight of nuts taken at harvest, which practically tripled previous average yields from this block of trees, is shown in table 8. Mr. Treat kindly furnished the yields from the trees over a period of eight years.

It will be noted that with the single exception of the crop of 1927, no annual yield was more than a third as great as that the year the trees were sprayed. The year 1927 was the most favorable to walnut production ever recorded in California.

Mr. Arch Wilson of Cupertino, California, who owns an orchard of

mature walnut trees, reported that bacteriosis had always severely attacked his crop prior to his use of spray. In 1930 and 1931 he sprayed with bordeaux 8–4–50 with consequent increase in crop and reduction in the amount of disease. Rows left unsprayed for checks clearly showed more disease than those sprayed.

Mr. Frank Leib of San Jose made the following interesting statement after his use of bordeaux 8–4–50 to control bacteriosis: "Overloading of the sprayed trees caused the nuts to be less completely filled but not enough to reduce the grade. To the eye the sprayed trees appeared to have twice as many nuts as the unsprayed trees. Nuts from trees on Royal hybrid root (Bolivian cross) were uniformly well filled, however, and the kernels plump, in contrast to those from trees on California black root."

In general Mr. Leib believed the spray to have improved the quality of the nuts, orchard run; in one of his orchards previous to the year he started spraying he harvested 10½ tons net of good-grade nuts and 60 bags of Babies. The first year he sprayed he harvested 24½ tons net of good-grade nuts, and only 18 bags of Babies, from the same orchard.

In the orchard referred to above, Mr. Leib has numerous commercial varieties growing. He sprayed all during the pre-bloom stage. By the time he had finished spraying his late varieties, the young nuts in the earlier ones had already passed the pollination period and were ready for the second spray. All varieties were sprayed twice. The Leib and Leib, an excellent variety extensively raised by Leib, had been attacked with increasing severity by bacteriosis for some few years previous to the use of spray. The clearing-up of the disease in this variety during the past two years has been striking.

Mr. A. P. Freeman of Lawrence Station, California, has owned an orchard of Santa Barbara Soft Shell Seedlings for twenty-four years. His average annual loss of crop to bacteriosis previous to spraying had been at least 80 per cent. There were years when the entire crop was destroyed. Because of the severity of the disease Mr. Freeman long ago removed most of the orchard and planted the ground to other crops. In 1930 he was planning to remove the balance of his trees but decided to spray. He applied bordeaux 8–4–50 during the pre-bloom stage with excellent results. In 1931 he sprayed again, and the writer visited the orchard before harvest. Bacteriosis was virtually nonexistent in the heavily loaded trees. Mr. Freeman regarded his control for the two years as practically 100 per cent. Although no trees were left unsprayed for checks, the severe attack on the crop in orchards in the general vicinity clearly showed that conditions there had been favorable to bacteriosis both years.

Mr. Walter Stevens of San Jose in whose orchard counts were made (table 1) in 1930, sprayed again in 1931 with bordeaux 8–4–50. For check trees Mr. Stevens left unsprayed a number of walnut replants of the same variety in an adjoining prune orchard. Unfortunately the age and size of the unsprayed trees varied too greatly to permit of an accurate comparison of weights and counts. Some of the unsprayed trees were as large as the sprayed trees, others were smaller, but all set a heavy crop at the beginning of the season. Little disease developed in the sprayed trees throughout the season, whereas the crop in the unsprayed trees was severely attacked. Shortly before the harvest an inspection of this orchard showed the ground under the unsprayed trees to be covered with blighted nuts. About 75 per cent of the crop that remained on the trees was diseased. The number of rotten nuts under the sprayed trees was negligible. The crop on the trees was excellent and showed very little bacteriosis.

Mr. Charles Anderson, in charge of the Anderson Orchard Company's large Payne walnut orchard on Archerdale Road, Linden, California, reported a control of the disease by spraying in 1930 which increased the crop 15 per cent.

Mr. Joseph Conner, manager of the Santa Clara Walnut Growers Association packing-house, sprayed some of the earlier varieties in his large orchard near Santa Clara in 1931 with bordeaux 8–4–50 in the prebloom stage. He reported a loss of 50 per cent in the unsprayed trees due to bacteriosis, whereas the loss was negligible in those sprayed.

Among other growers who have sprayed and reported successful results, often with considerable enthusiasm, may be mentioned Mr. W. H. Ward of Morgan Hill, Mrs. Glen Allen of Santa Clara, Mr. Galen Richardson of Byron, Mr. O. L. Freisinn of Santa Rosa, and Mrs. A. M. Moore of Ventura, all in California.

DISCUSSION

The prime object of the experiments has been to determine at what time or stage in the annual growth cycle of the walnut, sprays might be expected to control bacteriosis. Data showing the successful results obtained with sprays have been presented in the preceding section. It has been upon the accumulation of such data, as well as the writer's personal observations and experience, that the spray schedule recommended later on in this paper is based. It hardly seems necessary in a paper of this kind to present the accumulation of data, unsuccessful in character, which was obtained along with the successful. Much of it was obtained, however, and some of it has been used throughout the paper when necessary to the proper presentation and interpretation of successful results.

Experimental data obtained over a period of six years seem sufficient to justify the conclusion that the pre-bloom spray is absolutely indispensable and that its omission is almost certain to result in failure. In only one year were the climatic conditions in the locality where the experiments were being conducted such that the omission of the pre-bloom spray was not accompanied by untoward results. Thus the circumstances under which this spray can be safely dropped from any spray schedule recur so infrequently that it would be very unwise to chance omitting it. While best results ordinarily were obtained when the first application of spray was given during the pre-bloom stage as defined on page 35, there were exceptions to this rule; occasionally excellent controls were obtained slightly earlier, namely, when the buds were merely swelling and very little new growth had appeared; or even a little later, namely, when the young nuts not only had appeared but when some of them already had reached the size of peas. Control at this late date was very exceptional, however, and it may be expected to occur only when the climatic conditions preceding the application of the spray have been distinctly dry and unfavorable to infection. Spray applied at this stage also may interfere with fertilization of the nuts.

It has been shown in table 2 that the control exerted by a pre-bloom spray may persist, in part at least, until harvest. It may be stated frankly, however, that such results were the exception rather than the rule. It seems unnecessary to present data showing how a single pre-bloom spray may fail to control walnut bacteriosis. The dictates of common sense and a simple knowledge of the disease with its very long infectious period make it clear that an adequate control with a single pre-bloom spray ordinarily must be the exception rather than the rule. Negative data bearing on this point also might be misinterpreted; it might reasonably be questioned whether the failure was traceable to the unsuitability of bordeaux as a disinfectant to control bacteriosis or simply to insufficient applications of the spray. Data from the Campbell orchard (table 3) were included purposely to prove the latter to be true.

It is impossible to state how long the protective action of any one application of spray will last. The strength of the spray, its method of preparation, the climatic conditions, and the rate of growth of the susceptible tissues very definitely influence this point.

In tables 3 and 4 the benefits afforded by two applications of spray have been shown. It is impossible to secure figures that prove irrefutably that a second spray applied immediately after the nuts have set will nearly always produce greater benefits than one applied late—a month later for instance. But the experimental data and personal observations

strongly indicate this to be a fact. There may be exceptions. The crop increase resulting from a second application of spray in July to trees in the Bowman-Kuhn orchard (table 3) was as great as that in the Bishop orchard which was sprayed for a second time at a much earlier date. But this alone cannot be interpreted as proof that long intervals between sprays lead to as good results as short ones. On the contrary the *relative* increase in the Bowman-Kuhn orchard was less owing to the delay than in other orchards sprayed earlier but in which the yields were smaller for reasons other than bacteriosis. The Bowman-Kuhn ranch is well known in the Santa Clara Valley for its heavy yields, and the year of the experiment the crop was extraordinarily large. In spite of heavy losses by bacteriosis a large amount of the crop had not yet contracted the disease at the time the second spray was applied and was protected by it. Abnormally damp weather later in the season rather than early greatly influenced the situation in the Bowman-Kuhn orchard also.

Climatic conditions vary somewhat from year to year. Occasionally the deviation from the normal is extreme; in an abnormally dry year a delay in the application of the second spray after the nuts have set may produce no unfavorable results. But since there is no way of knowing when such extremes may occur it would be folly to risk the delay.

As indicated in the preceding section it has not been possible to show with figures the relative value of a third or fourth application of spray to control bacteriosis. Observational data confirming their value is abundant, however. For instance, in 1929 the Visalia Orchard Company's orchard (table 4) was given a pre-bloom and a post-bloom spray. In June, before the abnormally late rainfall of that year took place, there was an almost perfect control of the disease in the very large crop in the sprayed trees. The number of blighted nuts either in or under the trees was negligible. The crop in the unsprayed trees left as checks was severely attacked, and the ground beneath was covered with rotten nuts. After the June rains bacteriosis quickly established itself in the sprayed trees, which at that time were without protection since the spray residue applied two months earlier had largely been dissipated or outgrown. By harvest much of the crop had been destroyed. A third spray applied before the June rains very likely would have prevented much of the infection that took place so late that year.

Ordinarily sprays applied as late as June will be of little value because under normal conditions the rainy season in California will have been passed and the disease automatically checked as a consequence. Evidence of the kind given seems to justify the recommendation of sufficient sprays during the wet season to give the crop adequate protection.

DIFFICULTIES INVOLVED IN DETERMINING CONTROL OF BACTERIOSIS

There is no single, simple, and exact method of determining the extent of control of bacteriosis obtained with sprays. Numerous obstacles are encountered for which due allowance must be made if the results secured are to be properly understood.

Outbreaks of bacteriosis occur only when all of a number of conditions are favorable, consequently its occurrence is very irregular from season to season. Similarly the severity of the attack in the same locality may vary from orchard to orchard and even within one orchard. Hard and fast conclusions for or against a given treatment cannot be drawn from figures taken at widely scattered points in the same orchard. Fluctuation in the general size of the trees, particularly in large blocks, further adds to the difficulty of demonstrating with simple figures the indubitable fact that two sprays may give better results than one, three better than two, etc.

In contradistinction to the apricot, peach, and many other economic crops, walnuts are never thinned to produce uniformity of size and quality. The custom is to leave any and all nuts on a tree that it can produce. Up to a certain point, which will vary greatly with the vigor of the tree, the available moisture, the general environmental conditions, etc., it will produce the superior quality demanded by the trade, but beyond the optimum quantity for that tree under its environmental conditions, the quality and size become increasingly less satisfactory. This situation becomes all the more complicated in seedling trees, no two of which are just alike in their yield characteristics; some are always shy bearers while others regularly produce huge crops. Some produce small sizes only. Still others produce kernels of inferior quality regardless of the environment. To crowd more nuts on such trees beyond their optimum simply means the lowering of an already low standard of size or quality or both to a point which is unsatisfactory from the standpoint of the trade. A single example will serve to illustrate the point: In one orchard the crop set in 1927 was excessive. At harvest the nuts were highly unsatisfactory; the size was small, the average run of the orchard consisting of 50 per cent Babies. Jumbos were absent and there were exceedingly few Large-sized nuts. The great bulk of the larger nuts was, rather, of merely a poor Fancy size. To make the Diamond grade with such a product necessitated the employment of extreme methods in the packing-house, namely, exceedingly careful sorting by hand and vacuum machine and finally blending the nuts with better ones from other or-

chards. The following year the crop in this same orchard was thinned by frost. At harvest the average size and quality of the nuts were exceptionally fine; a high percentage of Jumbos prevailed and the Large size constituted the bulk of the crop. Babies were almost totally absent. The kernels were well filled, and the entire orchard run was of Diamond grade.

Bacteriosis often acts like frost and may be a blessing in disguise when trees are overloaded or environmental conditions are unsuited to the production of large crops. Unfortunately the disease usually thins the crop too much. But to protect the crop on overloaded trees from bacteriosis by sprays simply means a crop of nuts of inferior size and quality at harvest. Some growers have erroneously attributed such inferiority to poisonous effects of the spray. When not loaded beyond their optimum, sprayed trees produce nuts of satisfactory size and quality.

Weights Alone of Good Nuts Do Not Tell the Extent of Control.—Trees sprayed with bordeaux may present an unmistakably larger crop to the eye than those not sprayed and yet at harvest produce a very disappointing weight of nuts. In some instances no gain by weight will have been made at all. A careful measurement of the sizes and a crack test frequently will tell that part of the story not revealed by the weights; the extra nuts are there, but they are smaller in size, and perhaps inferior in quality also, as a result of overloading the trees. In certain tests made, sprayed trees yielded twice as many Babies and distinctly fewer Large nuts than unsprayed trees with crop thinned by bacteriosis.

It is when the disease proves particularly severe and cuts the crop badly on the unsprayed trees that the weight of the crop on sprayed trees, regardless of the size or quality of the nuts, may and frequently does show the real protective value of the spray. Figures covering such unmistakable control by weight are given in tables 2 and 3 (pages 40 and 42, respectively).

Counts Alone of Diseased Nuts Do Not Tell the Extent of Control.—Counts made of diseased nuts in or under sprayed and unsprayed trees may be very misleading when unsupported by other data.

It is easy to count the diseased nuts lying on the ground, less easy to count them while they are still hanging in the trees, because they are not so easy to see and many may be overlooked, thus leading to incorrect conclusions.

When the count of diseased nuts lying on the ground under unsprayed trees or hanging in them is vastly greater than that made in or under sprayed trees, as is often the case, there can be no doubt as to the

protective value of the spray. The difference in the weights of the crop will usually substantiate the proof obtained with counts.

At times, however, the weight of crop from sprayed and unsprayed trees may not show the great difference that the count of diseased nuts in or under the trees seemed to forecast. This puzzling fact may be explained in part on the grounds that severe infection of the crop may have taken place after the count was made and much of the crop destroyed. A count merely indicates the amount of disease visible at the time it is made. In 1929, for example, the loss in the Linden area was largely due to late infections which followed one of the wettest Junes ever recorded there by the United States Weather Bureau. Counts made in one orchard before the rains showed little disease in either the sprayed or unsprayed trees, but counts made after the rains showed a severe infection of the unsprayed nuts. At harvest results were considerably different than anticipated on the basis of counts made before the rains.

Most counts of diseased nuts are made only after they are large enough to be discerned readily on the ground or recognized in the trees. Such counts cannot and do not reveal the loss of very small nuts early in the season.

Theoretically the loss of very small nuts affected with the disease should be less from sprayed trees than from unsprayed. Accordingly it is reasonable to suppose that the weight of good nuts at harvest from sprayed trees would be even greater than percentage estimates based on counts made fairly late in the season would seem to forecast. Actually this seldom proves true; the factor of overloading usually enters and causes the nuts to be smaller and less filled so that there is ordinarily no more gain in weight than the counts would indicate. On the other hand, unsprayed trees with crop materially thinned by the disease early in the season may and frequently do produce larger and heavier nuts and as a consequence may yield almost as much by weight as sprayed trees. But if the disease has been very severe in the unsprayed trees the high count of diseased nuts will indicate a loss that will also show in the weights regardless of size or quality.

If large canvases were placed upon the ground under the sprayed and unsprayed trees at the very beginning of the season and counts of the diseased nuts that fell made at short intervals until harvest, a more accurate estimate of losses could be made. The difficulties involved make such an experiment impractical. Similarly, if all the healthy and diseased nuts in the sprayed and unsprayed trees were counted, the exact percentage of loss due to the disease could be determined, but the job would be an exceedingly laborious one.

Counting the diseased and healthy nuts in certain areas or at certain levels in the trees or on a given number of limbs is apt to lead to incorrect conclusions unless the work is done on a very large scale, because the disease often appears unevenly in the trees; it is usually worse at the lower, damper levels and on the north or cooler sides of the tree, but not always.

It is not always easy to secure satisfactory weights and counts in the same orchard; the method of irrigating orchards often precludes making accurate counts of the diseased nuts on the ground, as does the presence of weeds in orchards left uncultivated until harvest. In table 9, however, may be seen a striking control based on weights and counts in old seedling trees. Counts were made of all diseased and healthy nuts hanging in the trees which could be seen clearly within 15 feet of the ground. The plots were immediately adjacent to each other.

TABLE 9

COUNTS AND WEIGHTS OF DISEASED AND HEALTHY NUTS FROM THE SAME PLOTS OF SPRAYED AND UNSPRAYED TREES AT THE BISHOP RANCH, GOLETA, CALIFORNIA, IN 1930

Control as shown by counts

Treatment	Number of trees in plot	Total nuts counted	Number of diseased nuts	Per cent of diseased nuts
Sprayed	10	2,900	138	4.75
Unsprayed*	10	3,563	1,618	45.41

Control as shown by weights

Treatment	Number of trees in plot	Total yield good nuts	Average yield per tree, good nuts
		pounds	*pounds*
Sprayed	10	644	64.4
Unsprayed*	26†	988	34.5

* The unsprayed trees not only were larger than the sprayed trees but were in a better physical condition, having less heart rot, dieback, etc., thus throwing the burden of proof sharply on the figures obtained with the spray. The plots were immediately contiguous.

† Whereas the weight of the crop was taken from the 26 unsprayed trees, counts were made in only 10 of these same trees. To make counts carefully is a slow process and the smaller number of trees, typical of the block, was considered sufficient.

Similar results may be noted in tables 1, 2, and 3, which contain counts and weights, some of which were compiled in the same orchards.

There are other serious obstacles to a correct determination of crop yields on the basis of counts of diseased nuts alone; sprays applied at the wrong time may interfere with pollination and cause a heavy drop of the young nuts. Similarly improperly made spray may burn the nuts and cause many of them to fall. Trees with crop thinned as the result of either

or both may show very little disease indeed when counts are made, and yet at harvest yield a weight of nuts that is very disappointing. For instance a count of several thousand nuts made in unsprayed trees may show 20 per cent to be diseased. A similar count in sprayed trees may show only 10 per cent. But if 15 per cent of the crop was destroyed at the beginning of the season on the sprayed trees as the result of spray burn or interference with pollination by the spray, then the weights of crop at harvest may be less than that from the unsprayed trees in spite of the control of the disease. Examples can be given: In Oregon the orchards of R. Forbis at Dilley and J. O. Holt at Eugene showed a noteworthy control of the disease on the basis of counts alone (see table 1, p. 38). At harvest, however, the average yield per tree by weight was very much less than that from unsprayed trees. In the Holt orchard the sprayed trees averaged only 22 pounds, the unsprayed 41 pounds. The trees were sprayed twice, the second spray having been applied when the nuts were about the size of peas, a stage now known to coincide roughly with the period of fertilization. The spray also severely burned the trees according to H. P. Barss, who cooperated in this experiment. In the writer's opinion the apparent control of the disease indicated by counts and the loss of crop indicated by weights may be explained on the basis of spray burn or the interference with pollination by the spray, or both. Very serious spray burn also was reported in the Forbis orchard, which may have been responsible for the similar situation there.

In 1929 certain blocks of seventeen-year-old Payne walnut trees in the Anderson Orchard Company's orchard at Linden were sprayed experimentally during the pollination period. A heavy drop of small nuts followed. The remaining nuts developed very little disease. In midsummer the count of diseased nuts under the sprayed trees averaged 24, under the unsprayed trees 300. Mr. Charles Anderson, in charge of the orchard, made a count at a different period and found 500 diseased nuts under one unsprayed tree, 8 under an adjoining sprayed tree. At harvest, however, the sprayed trees yielded a smaller crop by weight than the unsprayed trees in spite of the severe attack of the disease in the latter. Interference with fertilization by the spray applied at the wrong time and consequent heavy drop of nuts is the probable explanation of the results obtained.

A crack test of the crop thinned by spray may show a distinctly improved size and quality. This was true in the Anderson orchard just referred to where the unsprayed trees were overloaded to begin with and not appreciably thinned by the disease until late in the season. Thus the nuts lost by spray injury may have been numerically greater than indicated by weight alone.

Weights of nuts from sprayed and unsprayed trees are concerned with quantity and tell little or nothing about the quality. Counts on the other hand are very untrustworthy as an index of quantity, but in making them a clue often may be revealed as to what the quality of the nuts will be; nuts infected very late usually are not destroyed, but they do not often escape being shell-stained, and stain throws them at once into culls, the lowest-priced merchandise. A count of the spotted nuts made late in the season will give some idea as to whether much of the crop will be shell-stained or not. For instance in the Anderson Orchard Company's orchard just referred to where the weight of nuts from unsprayed trees exceeded that of the sprayed it took four men working at top speed to pick the shell-stained nuts from the belt as they came through the vacuum machine and huller. It was one lazy-man's job to pick the few shell-stained nuts from the sprayed plot when they came through. Table 10 gives the figures obtained in the experiment.

TABLE 10

YIELD OF SHELLED-STAINED NUTS FROM SPRAYED AND UNSPRAYED TREES IN THE ANDERSON ORCHARD COMPANY'S ORCHARD AT LINDEN, IN 1929

Treatment	Number of trees in plot	Total nuts harvested in plot	Weight of shell-stained nuts		
			Total in plot	Average yield per tree	
				Wet weight	Dry weight
		pounds	*pounds*	*pounds*	*pounds*
Unsprayed	11	1,867	255	23+	18½
Sprayed	28	4,268	85	3	2½

In table 10 an allowance of 20 per cent for shrinkage in dehydrating has been made. Shell-stained nuts averaged 16 pounds per tree less in the sprayed plot than in the unsprayed. Shell-stained walnuts were worth 8 cents a pound that year at the cracking plant of the California Walnut Growers Association. The 16 pounds therefore were worth only $1.28. If they had been protected against the disease they would have brought about 20 cents a pound,[19] which was the average price for good Payne nuts, orchard run in that year, or $3.20 for the 16 pounds. Thus, there was a loss of $1.92 a tree due to stained shells alone. It cost between 70 and 80 cents a tree to make and apply the spray. A net gain of $1.12 to $1.22 a tree could have been realized on the basis of reduction of shell-staining alone.

[19] The prices for Payne walnuts, orchard run, for 1931 and 1932, which are the lowest ever set by the Association for this variety, would be less than the 20 cents average given above. Incidentally the culls would be worth less also.

Control Estimates Based Upon Personal Observations Are Not Always Reliable.—Control estimates made by merely looking at the trees are very untrustworthy when unsupported by other data such as weights and counts.

Only when the control of bacteriosis in sprayed trees is extreme can one be reasonably sure that it has occurred at all or that proof will be found in increased weights at harvest. An increase in numbers is more apparent to the eye than the slight decrease in size of the nuts and plumpness of the kernels which frequently result when trees are overloaded, factors which may influence the weights unfavorably.

On the other hand weights taken at harvest may reveal a certain amount of control by spray not appreciable to the eye when the crop is on the trees.

COST AND PROFIT OF SPRAYING

In tables 2, 3, 4, 6, and 7 the net gain in weight of nuts obtained by spraying has been shown. The question at once arises as to how much it costs for materials, labor, etc., to get the nuts. In short, does it pay to spray?

Bordeaux 8–4–50 is made of bluestone, lime, and water. Its preparation is discussed further on page 71. The prices of bluestone and lime fluctuate both with the year and with the locality in which it is purchased; they are higher in some years and in some localities than in others. Bluestone costs from 6 to 6¾ cents a pound in barrel lots (552 pounds). Good lime may be had from 1½ to 2 cents a pound in barrel lots (180 pounds). One gallon of bordeaux 8–4–50 at top prices costs a little more than 1 cent.

The cost of applying the spray varies greatly. It is cheaper in the long run to own one's spray equipment, particularly if the orchard is a large one. It is absolutely imperative to get the spray on at the right time if the best results are to be obtained. This is not always possible when the spray equipment must be rented. The prices charged by professional sprayers who furnish all necessary equipment and labor but not the spray material vary greatly according to the requirements of the work and the way the contract is drawn up. Ordinarily it costs from ¾ to 1½ cents a gallon to have the spray applied. These prices naturally include the sprayer's profit.

For average working purposes the writer estimates the cost of materials at 1 cent a gallon and the cost of applying the spray at 1 cent a gallon, or a total of 2 cents for each gallon of spray applied.[20]

[20] The average prices quoted above for labor and raw materials are considerably higher than those prevailing in 1931, 1932, and 1933. Bluestone could be had in large lots in some localities in 1932 and 1933 for one-half the price given above. The cost of a gallon of spray was less than 1 cent in 1931 and still less in 1932 and 1933.

The Amount of Spray Needed.—All parts of the tree must be thoroughly drenched with the spray. A mist or light fog which merely dampens the twigs and nuts will not do. A tree may be considered well sprayed only when all parts of it, inside and out, including the wood, foliage, and nuts, shine mirror-like in the sunlight. Unsprayed portions of the tree have a dull appearance in contrast. Excess spray that runs off is wasted.

Typical Examples of Spray Costs and Profits.—In table 11 typical examples of spray costs and profits realized by individual growers of

TABLE 11

COST AND PROFIT OF SPRAYING IN INDIVIDUAL ORCHARDS

Orchard	Year	Complete data in table No.	Number of applications of spray given	Total spray applied per tree		Increase in yield per tree		Net gain per tree from spraying
				Amount	Cost	Weight	Value	
				gallons	*dollars*	*pounds*	*dollars*	*dollars*
Bainbridge	1928	1, 2	1	15	0 30	20	4 00	3.70
Visalia Orchard Company	1929	4	2	40	0 80	19	3.80	3 00
Anderson-Barngrover Ranch Company Orchard	1927	2	1	10	0.20	6	1.20	1.00
J. G. Miller	1929	2	1	25	0.50	20	4.00	3.50
J. G. Miller	1930	....	1	30	0.60	33	6.60	6.00
Bowman-Kuhn Orchard	1929	3	1	....	0.36	24	4.80	4.44
			2	....	1.26	36	7 20	5.94

Payne and Concord walnuts are given. Profits have been computed on a basis of 20 cents per pound, orchard run, for good nuts of these varieties.[21] Cost of the spray has been estimated on a basis of 2 cents per gallon applied.

Mr. R. E. Barrett, entomologist of the Saticoy Walnut Growers Association, has submitted additional cost and profit data which he secured experimentally in three different orchards in Ventura County, California, in 1932. See table 12. Cost of making and applying the spray was 1¾ cents a gallon. Profits have been computed on a basis of 10 cents a pound for the walnuts, orchard run.

In a third orchard Mr. Barrett secured additional cost and profit data. See table 13.

The net profits indicated in tables 11, 12, and 13 are real or absolute only as far as the size and quality of the nuts were not impaired as the result of increasing the crop. An increase in quantity to the point of

[21] This estimate furnished by officials of the California Walnut Growers Association is the average price of a great many years. The price may be expected to fluctuate in individual years. In 1931 it was lower than the average, in 1932 still lower.

TABLE 12

DATA ON COST AND PROFIT OF EXPERIMENTAL SPRAYING SECURED BY R. E. BARRETT, ENTOMOLOGIST FOR THE SATICOY WALNUT GROWERS ASSOCIATION, VENTURA COUNTY, CALIFORNIA, IN 1932

Orchard	Trees			Treatment		Nuts produced			Total increase in yield, good nuts	Average increase yield per tree	Gross value of extra nuts	Gross gain per tree	Cost of spray per tree	Net gain per tree
	Variety	Age	Number	Spray	When applied	Total nuts	Good nuts	Blighted nuts						
						pounds	*pounds*	*pounds*	*pounds*	*pounds*	*dollars*	*dollars*	*dollars*	*dollars*
1	Wasson buds	10 yrs.	98	Bordeaux 8-4-50	Pre-bloom and post-bloom stages	7,224	6,998	226	461	4 7	46 10	0 47	0.23	0.24
			98	Un-sprayed	....	7,019	6,537	482	....	....	.....	.....	.....	.....
2	Placentia buds	9 yrs.	36	Bordeaux 8-4-50	Pre-bloom and post-bloom stages	2,737	2,685	52	588	16 33	58 80	1 63	0.23	1.40
			36	Un-sprayed	....	2,206	2,097	109	....	....			.....	.....

overloading the trees will result in decreased sizes and even decreased quality of the entire crop on the tree. Therefore an increase in quantity with no decrease in size or quality of the nuts may alone be considered

TABLE 13

ADDITIONAL COST AND PROFIT DATA SECURED BY R. E. BARRETT IN AN ORCHARD IN VENTURA COUNTY, CALIFORNIA, IN 1932

Trees			Treatment		Total yield	Average yield per tree	Increase in yield per tree		Cost of spray per tree	Net gain per tree as result of spray
Variety	Age	Number	Spray	Stage of trees when applied			Weight	Value		
					pounds	*pounds*	*pounds*	*dollars*	*dollars*	*dollars*
Placentia	21 years	301	Bordeaux 8-4-50	Pre-bloom and post-bloom stage	52,830	175.52	24.77	2.48	1.20	1.28
		24	Unsprayed	....	3,618	150.75	....	....	....	....

TABLE 14

LOSS SUSTAINED IN 1930 IN THE SEEDLING ORCHARD BELONGING TO RUSSELL ROWE, GOLETA, CALIFORNIA, AS THE RESULT OF IMPAIRMENT OF NUT SIZES OWING TO THE CONTROL OF BACTERIOSIS WHICH CAUSED THE TREES TO BE OVERLOADED*

Treatment	Nut yields, sizes, and values						Cost of spray per tree applied	Net loss per tree as result of spraying
	Grade sizes†	Per cent of crop‡	Pounds	Opening price of seedling nuts per pound in 1930§	Value of the nuts at 1930 prices	Gross gain per tree as result of spray		
				dollars	*dollars*	*dollars*	*dollars*	*dollars*
Sprayed¶	Baby	14⅜	19.636	0.15	2.95	0.65	1.10	0.35
	Fancy	25⅝	34.935	0.23	26.99			
	Large	38⅜	52.516					
	Jumbo	21⅝	29.907					
Unsprayed	Baby	7⅞	7.751	0.15	1.16	....	....	....
	Fancy	15⅜	15.179	0.23	20.99	....	....	....
	Large	32⅝	32.339					
	Jumbo	44⅛	43.724					

* For complete conditions of the experiment see table 2, p. 40.

† Seedling walnuts are graded according to size merely as Large and Baby. They have been graded here as if they were a fancy budded variety merely to show the great fluctuation in sizes of nuts from sprayed and from unsprayed trees.

‡ The average of six crack tests is given.

§ Large-sized seedling nuts may be packed as Diamond or Emerald according to the quality. In this experiment the Large-sized nuts from both the sprayed and unsprayed trees were Diamond and worth 23 cents per pound that year. The Babies were worth 15 cents.

¶ The oil combined with the bordeaux cannot be held responsible for the reduction in nut sizes. A considerable accumulation of data reserved for another paper shows that oil such as was used in this experiment usually tends to stimulate the production of large-sized nuts.

an absolute net gain. In table 14 the undesirable effect on nut sizes and values that may result when trees become overloaded as the result of controlling bacteriosis is shown. While the example is extreme it clearly illustrates the truth of the statement just made.

HOW TO SPRAY TO CONTROL BACTERIOSIS

Because walnuts are grown in California under widely diversified climatic conditions, any spray schedule proposed for the control of bacteriosis should be broadly applicable to the state as a whole and at the same time sufficiently flexible to permit of easy adaptation to the peculiarities of each individual locality. The problems of the damp coastal regions of northern and central California are considerably different from those met with in the drier portions of the great Sacramento and San Joaquin valleys or in the arid interior counties of southern California.

Even the strength of the spray is subject to considerable change. For the state as a whole, bordeaux 8–4–50, which may be regarded as full strength, is recommended. For its preparation see page 71. Experimentally the writer has obtained good control at times with spray at half this strength, namely, bordeaux 4–2–50, but several growers have reported unsatisfactory results with it. Since the stronger mixture has consistently given the best results over a period of years the general recommendation is for the stronger spray. There is no point, however, in using the spray at full strength if a weaker and cheaper mixture will meet the requirements of the control consistently and regularly year after year in any given variety or in any particular locality. The grower who has had no especial difficulty in controlling the disease with bordeaux 8–4–50 might try a few tanks of weaker spray in an experimental way. The weaker spray should be used alongside of the mixture at full strength under similar conditions and the results compared. Whatever the reduction in strength, the same 2 to 1 ratio between the bluestone and the lime should be observed; for instance, 6–3–50 or 4–2–50. No attempt to secure results with weaker mixtures should be made in advance of trials with the spray at full strength.

It is impossible to state the exact number of applications of spray necessary to guarantee a satisfactory or practical control of the disease in any one year or in any one locality, but at least two must be considered the minimum as a general recommendation. These may be insufficient in very damp regions or in years of greater rainfall in those regions normally dry. Many instances of striking control obtained with only one spray have been observed. Satisfactory control, however, with one application of spray must be regarded as the exception rather than the rule. There may be years when even two, three, or more sprays may fail to give the practical control sought for, although each additional application will help. Analogous examples are found in other well-known dis-

Fig. 14.—The pre-bloom stage in the development of the new growth when the first spray must be applied for best results in controlling bacteriosis. (Natural size.)

eases such as pear scab, *Coryneum* blight of peach and apricot, etc., which stubbornly resist control in spite of many applications of spray when climatic conditions are particularly favorable to their development.

The following general recommendations are based upon the personal observations of the writer and experimental data obtained at widely separated localities in California.

Winter Sprays.—The disease cannot attack mature or old wood, therefore it is unnecessary to protect it with winter or dormant sprays. The new growth (including the foliage and nuts) alone is susceptible. Sprays applied in midwinter largely will have lost their strength or disappeared by the time the new growth which needs protection breaks the bud.

The First Spray.—The first application of bordeaux 8–4–50 should be given in the spring when the buds are expanding and some of the new growth has developed but when few or none of the nuts have appeared. See figure 14. This is the strategic period for securing the maximum results with any one application of spray. This spray, which has been given the name of "pre-bloom spray," is absolutely indispensable, and it must not be omitted under any conditions in any part of the state or in any year, if spraying is to be done at all for blight. It is a clean-up spray that disinfects the trees, covers over the lesions which have been exuding the living parasites during the rainy winter months, and destroys any great accumulation of the latter on the buds and in more protected parts of the trees. Subsequent sprays are valuable, but each must be regarded merely as an auxiliary or helper to the first one.

To delay the application of the first spray beyond the general period described may result in a severe loss, particularly if many of the young nuts have become visible. The young nuts are exceedingly susceptible and may become infected as soon as they appear if climatic conditions are favorable. Incidentally the time it takes the nuts to develop to a point where they are ready for fertilization after their first appearance is very brief indeed. In some varieties the flower lobes actually are already expanded and receptive to pollination when the nuts are first exposed. Spray residue on exposed flowers may easily prevent fertilization and result in loss of the nuts. Hence the urgent need of a sufficiently early clean-up spray in the trees so that the nuts may be produced under conditions as disease-free as possible and without the risk of interference with their fertilization. See figure 15.

If the orchard is large and the spray equipment too limited to permit of spraying all the trees during the critical period mentioned, or if weather forecasts indicate that the weather will be stormy, then it is ad-

Fig. 15.—English walnut flowers in bloom. It is dangerous to spray at this stage of the development of the nuts because of the possible interference with pollination by the spray. (Natural size.)

visable to start spraying a little earlier than usual to insure the completion of the job on time. In general to meet emergencies it is better by far to spray just a little too soon than just a little too late.

If the orchard consists of seedling trees, which characteristically do not start growth activities in spring as a unit, the first application should be made when a few of the earliest trees have reached the pre-bloom

Fig. 16.—Young nuts of the English walnut after they have been pollinized. The dead flower parts are still visible. In some instances the fertilized fruit may be smaller or larger than that shown here. The second spray should be applied just as soon as the flowers have faded regardless of the size of the fruit. (Natural size.)

stage. Poor control will result in most years if spraying is delayed until the latest trees have reached this stage; the crop on the earliest ones may become badly infected while the grower is waiting for all of them to reach the proper stage for spraying. Best results will be obtained if the owners of seedling groves can apply the pre-bloom spray at intervals as the trees reach the proper condition for spraying. This will entail the expenditure of extra time and money, however.

The first spray should be applied when the vegetative or fruit buds have reached the critical stage described without consideration of the catkin development during this same period, because the time of catkin production varies greatly with the variety as well as with the season.

The Second Spray.—A second application of spray at full strength should be made as soon as possible after the fertilization period has passed. Figure 15 shows young nuts with flowers in bloom, the critical period in their development, when sprays must be withheld. Not until the bulk of the flowers have faded and turned brown is it advisable to spray the trees again.[22] At this time the nuts will vary in size from a pea to a small olive, according to the variety. See figure 16. The problem presented by the second set of nuts which ordinarily may be expected complicates the situation considerably, but it will be necessary to concentrate attention on the first set, which usually is the largest. This is particularly true if the weather has been wet. To delay because the second set of nuts is still receptive to pollination may mean an attack of disease that will occasion the loss of more nuts than the second set would ordinarily produce.

The second spray, like the first, is practically indispensable. Whereas the first spray disinfects and cleans up the trees, the second spray is the first to coat the young nuts with a layer of protective poison and give them individual protection. The tendency of most growers is to wait too long before applying the second spray.

The Third Spray.—Whether a third spray will be required will depend on the locality or the climatic conditions that prevail at the time. If the weather remains damp and there is much fog and rainfall it may be necessary to spray again, particularly if bacteriosis has started to appear and apparently is making headway. It should be remembered that from nine days to several weeks may elapse between the time the initial infection takes place and the time the spot first becomes visible. Consequently there may be many more diseased nuts in a tree than can be seen at any one time. Likewise it should be remembered that neither the spray nor its effects last indefinitely; the residue is constantly being shaken and washed off, and what little remains steadily loses its strength. Also as the nuts expand in size they grow away from the spray residue upon them, exposing new susceptible surface all the time. To hesitate about applying a third spray may mean a loss of much of the beneficial results obtained with the first two.

Most orchards are irrigated in late May or early June for the first time. Almost invariably there is a flare-up of bacteriosis after irrigations. The application of water to the trees causes the lesions on the nuts

[22] In a personal conversation with the writer Mr. Milo N. Wood of the United States Department of Agriculture, who has made intensive studies of walnut pollination, expressed the opinion that as long as any portion of the flower remains green there is still a chance for fertilization of the nut to take place if it has not done so already. Ordinarily the number of nuts fertilized after the flowers have faded perceptibly is not great, however.

and shoots to ooze a black slimy sap that is swarming with the disease-producing bacteria. It collects in drops and spatters down onto healthy nuts below (fig. 8, page 20). Insects also track it about. Probably many of the late infections can be traced to this source. If a third or another spray is considered advisable it should precede rather than follow the irrigation. It will be some little time after irrigation before the ground will be firm enough to bear the weight of a spray rig, and much infection may take place in the interim. By spraying just before irrigation all new as well as old susceptible surfaces will be given a fresh coating of protective material that will enable the nuts to withstand the effects of the irrigation better.

For practical purposes, regardless of whether irrigation is practiced or not, the third spray should be applied when the nuts average ½ to 1 inch in diameter. It should be kept in mind that there is a greater possibility that infection will take place while the season is damp and the nuts still small, than later, when it is dry and the nuts are larger.

There is no objection to using as many sprays as may be necessary to control the disease. Whether it will pay to spray two, three, or more times will depend upon the size of the crop, the value of the nuts, etc. If the crop set is small it may not pay to spray more than once. On the other hand the beneficial effects obtained may be lost if adequate protection to the crop is not given later on. The individual grower must solve this problem for himself. See "Cost and Profit of Spraying," page 57.

The Cumulative Effect of Sprays.—There seems to be a cumulative control produced by sprays applied to the same trees year after year; already certain growers who have been spraying regularly for four and five years have noted a marked annual decrease in the amount of bacteriosis in their orchards. It does not stand to reason that such a disease can be wiped out in one year once it has become firmly established, but time may show, as it has already shown in cases of other serious diseases, that persistent and correct spraying may gradually reduce its incidence to a point where costly multiple-spray methods no longer will be necessary and the disease will be held in check with a single spray.

REASONS WHY SPRAYING MAY FAIL

Many growers not wholly familiar with the details of bacteriosis frequently associate other walnut troubles, either vague or definite, with it that have no connection whatever. Since the spray schedule devised for the control of bacteriosis cannot possibly prevent or remedy these troubles it may be well to mention them. First, spraying will not bring about an increase in the natural set of nuts on the tree. It merely pro-

tects those set by nature itself. Spraying will not make light kernels out of "ambers" or prevent the light kernels from turning dark. Darkening of the kernels is occasioned largely by delays in harvesting, unfavorable climatic conditions, etc. Bordeaux can neither make plump kernels out of shriveled ones nor prevent the kernels from becoming shriveled. Inferior quality of this sort frequently is traceable to insufficient irrigation, sunburn, etc. Similarly bordeaux cannot be relied upon to increase the size of the nuts, although some growers believe they have seen evidences of its having done so. Spraying will not prevent moldiness of the shells or of the kernels of nuts which have lain on damp ground or which have become moldy in the husks while waiting to be gathered. The use of bordeaux is designed primarily to prevent, not cure, bacteriosis. No spray can cure the disease already established in the nuts, twigs, or leaves.

The following discussion is pertinent only to bacteriosis and its control.

Careless Spraying Leads to Poor Results.—Unless the entire surface of susceptible tissue is thoroughly coated with spray it is possible for it to become infected. It will pay the grower, therefore, to make every effort to spray his trees as thoroughly as possible. See "The Amount of Spray Needed," page 58, and "The Cost and Profit of Spraying," page 57, for further information on this subject.

Too Few Applications of Spray May Lead to Failure.—A typical example of failure to control bacteriosis satisfactorily as the result of the use of an insufficient number of sprayings may be seen in results obtained experimentally in the Campbell Orchard at Goleta (table 3, page 42), where the excellent control afforded by the first spray was lost in one block of trees when no additional sprays were applied. Trees sprayed twice in this orchard yielded an increase in crop that more than paid for both sprays, whereas those sprayed once did not produce enough extra nuts to pay for the single spray.

Delay in Application of the Sprays May Lessen Their Value.—In table 3, page 42, and table 4, page 43, examples of striking control with two sprays are shown. However, in certain instances, even better results could have been had if the second spray had been applied earlier than it was. In one or two cases the second spray was not applied until the disease had reached epidemic proportions.

Estimates of the amount of infection in the trees based upon the amount of disease that is visible are untrustworthy. In addition to the nuts actually showing the disease there may be many more that are already infected but which will not develop lesions for some time to come.

The tendency on the part of growers is to hesitate about making a second or third application of spray largely for financial reasons. Their viewpoint is not difficult to appreciate, but unless bacteriosis is kept under constant vigilance and the trees protected properly with sprays applied at the right time, the money spent will not bring satisfactory returns.

Sprays Too Weak in Strength May Fail to Produce Satisfactory Results.—The advisability of using weak spray mixtures is discussed under the heading "How to Spray to Control Bacteriosis," page 61.

SPRAY DAMAGE

The Interference with Fertilization of the Nuts by Spray Applied During the Pollination Period.—Heavy losses may be occasioned by the interference of spray applied to the open flowers during the pollination period. Heavy losses may also be occasioned by imperfect pollination that has no connection with spraying. Some varieties are notorious for their failure to produce pollen at the time the flowers are open. Others fail only in certain years to release their pollen at the time the flowers are receptive. Growers should not blame losses of this kind on spray that has been applied at the correct time for the control of bacteriosis.

Spray Burn and Other Undesirable Effects.—The walnut is peculiarly sensitive to injury by spray materials that ordinarily have no bad effects on most other plants. Bordeaux 8–4–50 was found to be the least injurious of the many materials tried in the course of the experiments. In fact over a period of five years at widely separated points in the state and under the most diversified climatic conditions no spray burn was observed in any of the experiments. The possibility of bordeaux spray burn is acknowledged, however. From time to time growers cooperating with the writer reported burning of the foliage by the spray.

Ordinarily the burns occasioned by properly made bordeaux spray are of no great consequence. The damage is quickly outgrown and the crop in no way affected. Improperly made bordeaux may burn the walnut severely, or any other plant, for that matter.

The new tender foliage is susceptible to burn while it is still reddish in color. As it matures and turns green its resistance increases greatly. Fully developed foliage will tolerate repeated applications of bordeaux at full strength. Spray burn usually manifests itself by a withering and drying out of the leaflets (fig. 17). Frequently the margins alone are killed and distortions result when the living tissue grows away from the dead areas. Killed spots, circular or irregular in outline, may also develop on the blades. The killed tissue may fall out after it dries so that

the leaf becomes perforated and ragged in appearance. No actual defoliation in any appreciable amount occurs.

The factors that lead to spray burn of walnut foliage are imperfectly understood. Trees may be susceptible to the injury one year in a certain locality but not the next. This suggests the possible influence of climatic

Fig. 17.—Spray burn of English walnut foliage. The shoot on the right is normal. The shoot on the left shows the characteristic perforation and desiccation of the leaflets. (Two-thirds natural size.)

factors. Most burning seems to take place when the sprays are applied during hot windy weather when the humidity is low, but exceptions to this observation have been noted. It might be advisable to avoid spraying on warm days when the humidity is low, such as prevail at times in southern California.

Mr. Floyd Stone, in charge of one of the Bowman-Kuhn orchards at San Jose, has sprayed with bordeaux 8–4–50 for a number of years (see table 2, page 40, and table 3, page 42) with and without spray burn. His crop yields have been excellent. At the writer's request Mr. Stone tried different bordeaux formulas on large blocks of trees in an effort to find a mixture that would not burn the foliage under the conditions peculiar to the orchard. The results were unsatisfactory. When equal amounts of bluestone and lime were used, the spray burn was just as severe as when bordeaux 8–4–50 was used. Similarly, bordeaux used at half the usual strength, namely 4–2–50, occasioned as much burn as the mixture used at full strength. The method of mixing the spray seems to

have little bearing on the matter; the addition of either the lime or the bluestone to the tank first will not render the spray less likely to burn the foliage when climatic conditions are conducive to it.

Some growers have reported that bordeaux spray to which about 1 per cent of highly refined emulsified oil (100 per cent unsulfonated residue) has been added is less likely to burn the foliage than the straight mixture. Mr. Stone tried less highly refined oil emulsions at the same strength with the same object in view.[23] These oils were used because they are considerably cheaper. There seemed to be less burning where the combination was used, although it was not entirely prevented.

The Franquette, Mayette, and Eureka varieties seem more susceptible to spray burn than either the Payne or the Santa Barbara Soft Shell.

Mechanical Injuries Occasioned by the Spray.—Spray applied under pressure is likely to bruise and tear the foliage, particularly on the lower branches. Bruised and lacerated tissue may die and leave spots or perforations. Injured tissue may be damaged further by spray burn. Mechanical injuries of this kind are quickly outgrown and may be ignored. The proper manipulation of the spray gun when spraying the lower limbs will obviate much of this kind of damage.

THE PREPARATION OF BORDEAUX SPRAY

The ingredients which make up bordeaux spray are bluestone (copper sulfate), quicklime (calcium oxide), and water.

To designate the proportions of bluestone and quicklime used it is customary to write the formula immediately after the name of the spray, such as bordeaux 8–4–50. In such a formula the first figure always indicates the number of pounds of bluestone used, the second figure the number of pounds of quicklime, and the third figure the number of gallons of water.

The grower who intends to spray regularly, particularly if the orchard is a reasonably large one, should familiarize himself with the great advantages of an elevated platform from which concentrates or stock solutions can be run directly to the spray tank with less trouble, delay, and muss than when the spray must be mixed from barrels on the ground. An overhead water supply of good volume is practically indispensable. Also, for cleanliness and convenience, a level concrete base and

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[23] The oil emulsions used were Orthol-K-Medium and Medium Summer Oil, manufactured by the California Spray Chemical Company, Berkeley, California, and the San Jose Spray Manufacturing Company, San Jose, California, respectively. Ordinarily neither emulsion is toxic in itself to walnut foliage.

drain for the spray rig to stand upon when the spray is being made, or when the tank is being washed out, is much to be recommended.

The following method is designed for the grower who has few or none of the conveniences described above, but in general the principles involved are the same as used in any method of making bordeaux.

Preliminary Preparations.—First, secure at least 4 water-tight, clean wooden barrels of 50-gallon capacity. To work with less than 4 barrels will delay the work of spraying, and since the nature of the disease is such that everything must be done to facilitate the job of spraying, it is poor economy to work with too few barrels. If the orchard is large and much spray is to be used, 6, 8, or even more barrels, will be found to be none too many once the work is under way. See that the barrels are thoroughly clean and well soaked up. Provide a coarse bristle brush and an extra barrel of water for the purpose of washing buckets, etc.

Place the barrels on level ground in a position convenient to the water supply. With a bucket or other liquid measure, the capacity of which is definitely known, very accurately pour 40 gallons of water into each barrel. Drive in two brass or copper nails opposite each other on the inside of each barrel at the 40-gallon level. Do not remove the nails, because the barrels will be used again and again. Empty the barrels.

Preparation of Stock Solution of Bluestone.—In each of two or more barrels, in which the 40-gallon level has previously been determined, dissolve 80 pounds of bluestone. The bluestone should be of good grade, which may be recognized by its deep blue or sapphire color. A green color indicates the presence of iron impurities, and such bluestone should be rejected. Place the bluestone in a clean, fairly loosely woven gunny sack free of holes. Avoid the use of heavy interwoven sacks which do not permit of free circulation of water within. Tie the sack closely to a wooden bar of some sort such as an old axe, pick, or broom-handle and suspend the bluestone in the middle of the empty barrel in such a way that it touches neither sides nor bottom. Pour boiling hot water into the barrel to dissolve the bluestone.

Boiling water is easily obtained as follows when no more convenient source is at hand: Dig a fairly deep trench close to the water supply and away from the wind. Place four iron bars or pieces of pipe across it to support two ordinary 10-gallon wash tubs full of clean water. The tubs should be provided with flat tin lids. Build a good fire in the trench, which for the sake of convenience should be dug not wider than the tubs. The contents of the two tubs (roughly 20 gallons) will quickly come to a boil and will be sufficient to dissolve the bluestone in one barrel in a few minutes. Cold water may be added either before or after all of the bluestone has dissolved to bring the water level up to the 40-gallon mark. If

luke-warm water is used it may take several hours to dissolve the bluestone. If cold water is used it may take several days, according to the chill of the water. To speed up the solution of the bluestone, the sack may be shaken from time to time.

When the last bluestone crystals have disappeared remove the sack from the barrel. Carefully note whether the solution has reached the 40-gallon mark. If not, add the necessary amount of cold water to bring up the level. Stir the solution with a wooden paddle until it is evenly mixed throughout. Once thoroughly mixed it needs no further stirring at any time, and the paddle may be removed. The barrel now contains 40 gallons of bluestone stock solution (not 40 gallons of water) in which 80 pounds of bluestone have been dissolved. Each gallon of solution, therefore, contains 2 pounds of bluestone. The stock solution is ready for use.

Under no circumstances prepare bluestone stock solution in an iron barrel or other vessel in which iron is exposed because the bluestone will destroy it. Even iron nails used to mark levels in barrels will disappear, necessitating recalibration of the 40-gallon level.

Preparation of Stock Solution of Lime.—Since only one-half as much quicklime is used as bluestone in the bordeaux 8–4–50 formula, smaller quantities of lime stock solution may be made.

In one or more clean, empty wooden or iron barrels, the 40-gallon level of which has previously been determined, dump 80 pounds of good-quality, freshly burned quicklime (unslaked lime). Add cold water until the quicklime is almost covered, and allow the mixture to come to a boil of its own accord. Sluggish lime which will not raise the temperature of the water to the boiling point should be returned to the dealer who supplied it. Quicklime rapidly deteriorates on exposure to the air and becomes "air-slaked." As the quicklime air-slakes it sloughs away from the lump form in which it usually comes, into a very fine, flour-like, white dust. The presence of much of this white dust in the barrel should cause it to be looked upon with suspicion. Air-slaked lime is utterly worthless in the preparation of bordeaux, and serious burns may result if it is used. Many companies manufacturing quicklime realize the difficulty of keeping it fresh in wooden barrels and now pack their product in air-tight tin drums. Such quicklime if originally obtained from a good quarry is apt to be the best. Some companies using metal drums pulverize the quicklime to conserve space. Such pulverized or powdered quicklime is as good as any provided it is fresh. In such cases the readiness and thoroughness with which it reacts with water will be the sole proof of its freshness.

Some pulverized quicklimes of high purity, packed in metal drums, are so violent in their reaction with water that it is often desirable to start with the barrel about two-thirds full of cold water instead of empty as described above. The requisite amount of quicklime should be poured into the water at a rapid rate. Ordinarily the entire amount can be introduced into the barrel before the temperature of the water is raised to the boiling point. If the mixture becomes violent before all the quicklime has been introduced, the worker should wait a moment until the reaction subsides. Or the temperature can be lowered by the addition of more cold water to the barrel, after which the remainder of the quicklime may be added conveniently.

The quicklime should be stirred occasionally while it is being slaked to insure that water reaches all of it. Add water from time to time to prevent the mass from drying out and finally enough to bring the level up to the 40-gallon mark. After the reaction is complete and boiling has ceased, the mixture should be stirred vigorously for a few minutes until all lumpy material or paste in the bottom of the barrel has disappeared and a smooth "milk of lime" obtained. Small quantities of impurities such as grit, rock, or unburned lime may be ignored.

The barrel now contains 40 gallons of lime stock solution (not 40 gallons of water) in which 80 pounds of quicklime have been slaked. Each gallon therefore contains 2 pounds of quicklime. The lime stock solution is ready for use.

Preparation of the Spray from the Stock Solutions.—The stock solutions of bluestone and lime should be made at a convenient time before they are apt to be needed. Each one separately keeps practically indefinitely but when one is added to the other the resultant mixture must be used at once, as it deteriorates rapidly on standing, losing both its adhesive properties and its value as a disinfectant.

The spray should always be prepared with cold water. There is no objection to using the stock solutions while they are still hot, however, if the following method of mixing the spray is observed.

First determine the amount of bluestone and lime stock solution that must be used to make a tank of bordeaux 8–4–50. The formula itself provides for 50 gallons of spray only. Multiply the numbers of the formula by the number of times that 50 gallons will go into the spray tank. The calculations for 200, 300, and 400-gallon tanks would be as follows:

8–4–50	8–4–50	8–4–50
× 4	× 6	× 8
32–16–200	48–24–300	64–32–400

Thus for a 200-gallon tank, it will be necessary to use 32 pounds of bluestone and 16 pounds of quicklime as shown above. Since each gallon

of the stock solutions contains 2 pounds of either bluestone or quicklime, it will be necessary to take 16 gallons of bluestone stock solution and 8 gallons of the lime stock solution to give the requisite amounts.

The amount of stock solution to use in tanks of other sizes is determined in exactly the same way; thus for a 400-gallon tank, take 32 gallons of the bluestone stock solution and 16 gallons of the lime stock solution to give the requisite amounts of bluestone and quicklime.

Dip the bluestone solution with a wooden bucket; it destroys iron pails quickly. Always wash the pails after finishing with one solution before using them in the other.

To mix the spray proceed as follows: First fill the tank ½ to ⅔ full of clean, cold water. Next add the bluestone stock solution through a sieve of about 20 meshes to the inch, to exclude grit and other foreign substances which otherwise may reach the valves or nozzles and give trouble. Start the agitator running, and add the requisite amount of lime stock solution last. Always stir the lime stock solution vigorously before drawing, because the lime tends to settle out on standing. If the solution is thoroughly stirred each time before using it will be no more concentrated at the bottom of the barrel than at the top. When the lime stock solution is thoroughly mixed it should run freely through the sieve into the tank. Lime stock solution that is pasty may be hosed through the sieve easily. Carefully remove the sieve and shake out the grit, dirt, and other débris.

Fill any space that may remain in the tank with water and proceed to spray at once. Never stop the agitator at any time after starting to mix the spray until the last of it has been applied to the trees.

Opinions are divided as to whether the bluestone or the quicklime should be added to the tank first. There seems to be little difference in the bordeaux produced by the two methods or in the effects produced on the walnut tree. The writer has always added the bluestone to the tank first and the lime last with excellent results.

Stock solutions left over may be saved for use later on. Drive a copper nail at the level of the solution when finished with it. Just before using the solution add water to bring the level up to the nail, to replace the water that has been lost by evaporation. Stir the mixture vigorously, and the original 2-pounds-to-a-gallon ratio will be restored.

The Use of Commercial Bordeaux.—The use of bordeaux powders in which the bluestone and quicklime have been combined chemically is not advised. The adhesive properties of such powders are very poor and their value as disinfectants distinctly inferior to those of freshly prepared bordeaux.

So-called "two package," "twin," or "instant" bordeaux more closely approximates the freshly prepared spray than does the powdered form. In such preparations the bluestone is contained in one bag, lime in another. The bluestone is powdered fine enough to dissolve readily in cold water when added to the tank, thus obviating the use of hot water as described earlier in this section. The lime is already slaked (hydrated) and need not be prepared in advance as when quicklime is used. Some bordeaux chemists not averse to commercial bordeaux of this type recommend soaking the hydrated lime overnight in water, however, before making the spray, for best results. This, of course, necessitates the use of barrels as when bordeaux is made from quicklime.

The greatest recommendation of commercial preparations of this type is the ease with which bordeaux spray can be prepared from them. They possess certain objectionable features, however, which may lead to serious trouble at times. Dry hydrated lime when exposed to air is readily converted into a carbonate and as such is utterly useless in the preparation of bordeaux. The paper bags in which the hydrated lime is sold are not wholly impervious to air. Likewise they are easily punctured; this permits air-slaking to take place, though the change is not evident in the appearance of the material. The more reputable manufacturers recognize this danger and replace it in the market with fresh material after a reasonable length of time. Severe burns may result when old lime is used.

There can be no objection to the use of pulverized bluestone in the preparation of bordeaux spray provided the price is satisfactory and the material ground fine enough to permit of complete and immediate solution in cold water when it is added to the tank. The writer has used some commercial products, however, which did not dissolve readily but collected in the corners and bottom of the spray tank. This may happen even with the best material if sufficient agitator blades are not used or if some of them are not properly adjusted. Undissolved bluestone sprayed on the foliage will cause burns. Freshly prepared bordeaux spray was used exclusively in all the experiments reported in this paper, but certain excellent results have been obtained by walnut growers with the two-package type. From the standpoint of cheapness and efficacy, home-made bordeaux, the preparation of which is described on page 71, cannot be excelled.

LIST OF MATERIALS TRIED WITH DOUBTFUL, LIMITED, OR UNFAVORABLE RESULTS

For the sake of record a report is given here of the various spray materials tried with limited, doubtful, or unfavorable results. Some of the materials seemingly produced good results on their first trial but failed to repeat them in subsequent experiments. Others burned the foliage or poisoned the trees. As a whole they may be regarded as failures. Individual materials need be discussed in detail sufficient only to show why they were unsuited.[24]

Highly Refined Oil Emulsions (Unsulfonated Residue 100 per cent).—Several types were used at 2 and 5 per cent strengths in single and multiple applications as described on page 33. They afforded no protection whatever.

Basic Copper Acetate.—This material was used at the rate of 4 pounds in 50 gallons of water, either with or without ground glue (previously dissolved in hot water) at the rate of 1 pound to 50 gallons of spray as an adhesive. Single and multiple applications were given as described on page 33 for a period of three years. Basic copper acetate afforded an appreciable amount of control at times, but bordeaux 8–4–50 used alongside of it under identical conditions consistently gave better results. At times there was a distinct tendency on the part of the copper acetate spray to russet the foliage and nuts. This was avoided by reducing the strength from 4 pounds to 3 pounds in 50 gallons of water.

Ammoniacal Copper Carbonate.—The standard formula was used:

Copper carbonate	5 ounces
Ammonia (26° Baumé)	3 pints
Water	50 gallons

Used in moving plots over a period of several years, this spray, like basic copper acetate, afforded an appreciable amount of control, but was inferior to bordeaux 8–4–50. Unlike basic copper acetate it did not burn or russet the foliage.

Borco, a proprietary product said to produce ammoniacal copper carbonate when dissolved, was used at the rate of 12 pounds in 200 gallons of water. Borco Spred at the rate of 1 pound in 200 gallons of the spray was added according to the directions of the manufacturers.[25] Used in

[24] Many of the chemical and proprietary spray materials reported here as failures in the control of walnut bacteriosis have been found highly effective in the control of other plant diseases. It was their success in other fields that led to their use in the present experiments. The fact that they failed to control bacteriosis should not prejudice growers against their use in fighting diseases for which they may be better suited.

[25] "Borco" and "Borco Spred" are manufactured by the Rex Research Company Inc., of Toledo, Ohio.

moving plots as described on page 33 the results were identical with those obtained with freshly prepared ammoniacal copper carbonate.

Acid Bordeaux.—A solution of bluestone (8 pounds to 50 gallons of water) was treated with such small amounts of quicklime (previously slaked in water) that the resultant bordeaux was definitely acid to litmus. After 10 minutes' agitation some of the spray was filtered and the filtrate tested with a solution of potassium ferrocyanide for the presence of soluble copper. A bright rose or pink color was produced, showing copper to be present in the filtrate.

Acid bordeaux was applied in moving plots as described on page 33. Its action was undependable; rather severe burns were occasioned one year and not the next. The worst damage occurred on the trees to which the spray had been applied several times.

While acid bordeaux showed distinct disinfectant properties (see table 2, page 40), the control afforded by it was no greater than that of the alkaline mixture. Its greater tendency to burn the foliage and the difficulty of preparing it make its use inadvisable.

Neutral Bordeaux.—Prepared exactly like acid bordeaux but with the addition of more quicklime to make the spray neutral to red or blue litmus. The filtrate when tested with potassium ferrocyanide failed to show the presence of copper ions.

The results obtained with neutral bordeaux were practically indistinguishable from those of acid bordeaux. Undependable in its action on the foliage, it sometimes occasioned pronounced burns, at other times no appreciable damage. Its use by growers is not considered advisable.

Excessively Alkaline Bordeaux.—Various bordeaux formulas were tried in which the quicklime content varied in weight from an amount equal to that of the bluestone used to twice as much. None of these sprays afforded any greater control than bordeaux 8–4–50. Sprays of this type are harder to apply and leave a very dense, opaque residue resembling whitewash, which is highly undesirable on the shoots and foliage. When bordeaux 6–12–50 was used, the very great excess of lime present was injurious to the valves and pressure regulator of the spray pump. The seating pin in the latter had to be replaced from time to time as the result of the abrasive action of the spray.

Semesan.—Semesan (hydroxymercurichlorophenol sulfate 30 per cent, inert material 70 per cent) formerly was manufactured by E. I. Du Pont de Nemours and Company of Wilmington, Delaware, and was used in moving plots on Payne walnut trees at the rate of 0.25 per cent for the first two applications. In blocks of trees receiving the third and fourth applications in summer, the strength was cut to 0.12 per cent, because it was observed that with the approach of warm weather the

foliage sprayed with the stronger concentration turned yellowish and at times showed a faintly speckled condition reminiscent of, but not always identical with, true spray burn. Even at weaker concentrations the material applied in midsummer induced this same condition in trees sprayed for the first time. In another moving plot, the experiment was duplicated in every detail except that Volck oil, 2.0 per cent in strength, was used in combination with the Semesan.

In all blocks of trees sprayed with Semesan alone or in combination with oil, there was no appreciable control of the disease regardless of the number of applications given.

The trees appeared to be normal at the close of the season, but during the following winter they died back badly, in many instances almost to the main trunk, regardless of the strength at which the material had been used or whether it had been combined with oil or used in single or multiple applications. The severest damage was observed in the blocks receiving multiple applications of the spray. Symptoms of poisoning were very apparent the following spring; the new foliage appeared much later than that on adjoining unsprayed trees and was yellowish in color. Growth was sluggish throughout the season. *Melilotus* seed planted for a covercrop during the winter failed to germinate under the trees sprayed with Semesan. Outside of the sprayed plots, however, there was a luxuriant growth waist high.

Uspulin.—Uspulin (hydroxymercurichlorophenol sulfate 30 per cent, inert material 70 per cent) formerly manufactured by the Bayer Company of Rensselaer, New York, has been withdrawn from the market. It was used at the rate of 0.25 per cent with and without 2.0 per cent Volck oil in moving plots on Payne walnut trees, from one to four times. As in the case of Semesan the strength of the Uspulin had to be reduced to 0.12 per cent with the approach of warm weather. Uspulin alone or in combination with oil produced highly undesirable effects, identical with those produced by Semesan, regardless of its strength or whether it was used in single or multiple applications. A comparison of the weights of nuts from sprayed and unsprayed plots adjoining revealed no appreciable control of the disease. The quality of the nuts from sprayed trees was distinctly inferior to those from unsprayed trees. During the winter following the experiment the sprayed trees died back badly. *Melilotus* seed planted for a covercrop failed to germinate under the sprayed trees.

Dip Dust.—Dip Dust (hydroxymercurichlorophenol sulfate 6 per cent, hydroxymercurinitrophenol sulfate 2 per cent, inert ingredients 92 per cent) formerly manufactured by the Bayer Company of Rensselaer, New York, has been withdrawn from the market. Used at 0.25 per cent

strength it gave considerable promise, but final conclusions could not be drawn under the conditions of the experiments. Large blocks of trees sprayed one and two times with it early in the growing season of 1928 were seemingly unaffected in any way. The crop was lost to frost, however, and the value of Dip Dust as a disinfectant could not be determined. The following year with limited material available, 11 trees were sprayed a single time with it when the nuts were about the size of peas. No ill effects were noted throughout the balance of the season. In a part of the orchard where the natural set of fruit varied considerably, the trees sprayed with Dip Dust produced a huge crop, averaging 216 pounds hulled nuts per tree, wet weight, against 171 pounds average on 11 check trees seven rows away. Dip Dust was very expensive, and it is doubtful whether it would pay to use it regularly. Dip Dust was almost entirely colloidal and practically insoluble in water in contradistinction to Semesan and Uspulin, which were almost entirely soluble.

Neko.—Neko is a germicidal soap containing 2.0 per cent mercuric iodide manufactured by Parke, Davis, and Company of Detroit, Michigan. It was used at strengths varying from 0.25 per cent to 0.10 per cent on Payne walnuts. Even at the weaker concentration it caused severe burning of the leaves, retarded the growth of the new shoots, and stunted the nuts in size. Pending further experiments its value as a disinfectant must remain undecided.

Iodine.—A saturated alcoholic solution of iodine was prepared by placing an excess of iodine crystals in methyl alcohol. The solution was used at 0.50 per cent strength in water in which 2.0 per cent fresh quicklime previously had been slaked. Also it was applied as weak as 0.06 per cent in water containing 1.0 per cent cooked cornstarch, added as an adhesive. At any strength at which it was used the iodine caused severe burning of the foliage of Payne walnuts, delayed the new growth, and stunted the nuts in size. No trees were sprayed more than once with iodine in any dilution because of the severe reactions which it caused. After two years' trial this element was considered unsuited for use as a disinfectant on walnuts.

Liquor Cresolis Compound, Surgical.—A liquid soap containing 50 per cent Cresol, U. S. P., manufactured by the Michel and Pelton Company of Oakland, California, used at 0.5 per cent strength in water, in which 1.0 per cent fresh quicklime had previously been slaked. Payne walnut trees were sprayed with the mixture when the new growth was starting in the spring and again when the nuts were the size of peas. No ill effects were noted. The crop was destroyed by frost, consequently the value of the spray could not be determined. Used the following year only once at 0.35 per cent strength without any lime on 11 trees when

the nuts were the size of peas, the mixture occasioned no injury. The disease developed as early on the sprayed trees as on check trees close by, and a comparison of the weight of nuts from the two plots at harvest showed no evidence of control. The possibilities of this material were not exhausted, but in view of the volatile nature of its active principle it is not likely that bacteriosis can be effectively controlled with it.

Sodium Fluosilicate.—Sodium fluosilicate was applied at the rate of 8 ounces in 400 gallons of water to Payne walnut trees from one to four times in moving plots. In a similar moving plot the material was applied from one to four times at the same strength in combination with 2 per cent Volck oil. The cumulative effect of the sodium fluosilicate was very bad, either when used alone or in combination with oil. Even at the very weak concentration at which it was used it burned the foliage severely. No control of the disease was effected, there being just as many good nuts harvested in the check plots on all sides as in any of the sprayed blocks.

Calcium Chloride.—Calcium chloride was used at the rate of 1.0 per cent concentration in water from one to four times on Payne walnut trees in moving plots. In a similar moving plot this material was used again at the same strength in combination with 2.0 per cent Volck oil. Used alone or in combination with oil the calcium chloride produced undesirable effects on the trees. Less apparent in plots sprayed once, spray burn was very noticeable in plots sprayed several times. The material effected no appreciable control of the disease; the crop was just as large by weight in check plots on all sides as in the plots sprayed with calcium chloride alone or in combination with oil.

Potassium Permanganate.—Potassium permanganate was used at 1.0 per cent concentration in water in limited experiments from which no final conclusions as to its worth as a disinfectant could be drawn. The material occasioned no damage to the trees. Because of the rapidity with which potassium permanganate loses its disinfectant properties it is not likely to prove satisfactory as a spray in the control of walnut bacteriosis.

Zinc Sulfate and Quicklime.—The method of preparing the spray is similar to that of bordeaux. The formula used was 4–4–50. The zinc sulfate was added to a spray tank about two-thirds full of water. The agitator was started and the lime (previously slaked separately) poured in. The tank was then completely filled with water.

This mixture was tried only once on Payne walnuts during the prebloom stage. There were no appreciable results. The experiment was never repeated and no final conclusions were drawn.

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